WHITE PAPER

USDA Forest Service   Pacific Northwest Region   Umatilla National Forest

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Range of Variation Recommendations for Dry, Moist, and Cold Forests[1]

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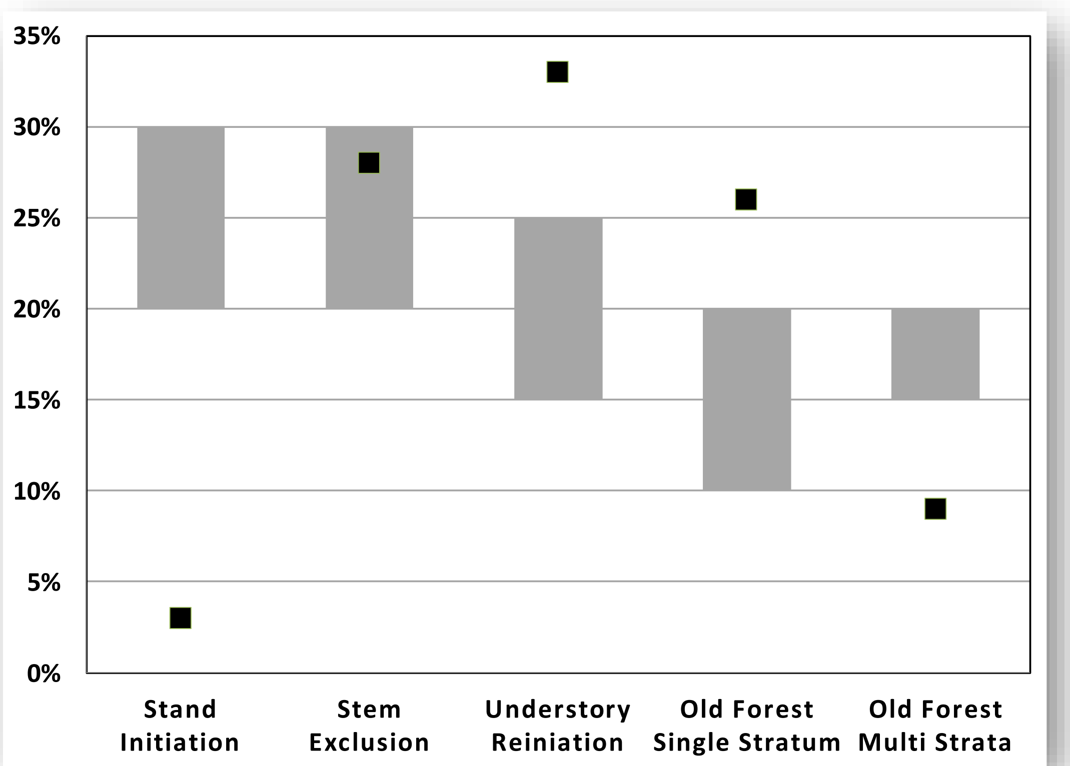

[1] White papers are internal reports receiving only limited review. Viewpoints expressed in this paper are those of the author – they may not represent positions of USDA Forest Service.

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INTRODUCTION

The range of variation (RV) is defined as a range of conditions likely to have occurred in the Blue Mountains prior to Euro-American settlement in the mid-1800s (USDA Forest Service 1996).

The RV concept has been a recurring theme in forest ecology and management literature for at least two decades now (Aplet and Keeton 1999, Caraher and Knapp 1994, Christensen et al. 1996, Dodson et al. 1998, Egan and Howell 2001, Kimmins 1997, Manley et al. 1995, Millar 1997, Morgan 2004, Morgan et al. 1994, Morgan and Parsons 2001, Parsons et al. 1999, Quigley and Arbelbide 1997, Swanson et al. 1994, USDA Forest Service 1992).

"Considerable attention has been focused on natural disturbance processes as a guide for forest management. Concepts such as the historic range of variability (Landres et al. 1999) and coarse filter conservation strategies (Haufler et al. 1996, Hunter 1990) suggest that successful management of ecosystems may best be achieved by mimicking natural disturbance patterns and processes" (Wright and Agee 2004:443; Arno and Fiedler 2005, Perera et al. 2004).

Terminology note: Some sources refer to RV as a natural range of variability (Hessburg et al. 1999, Swanson et al. 1994) or an historical range of variability. Natural is an ambiguous but frequently used term to signify something of esthetic or spiritual importance (Christensen et al. 1996).

Primarily to avoid this ambiguity, I use the term 'range of variation,' although 'range of variation' also agrees with Forest Service handbook and manual direction (see FSH 1909.12, section 43.13 – Range of Variation; and FSM 1920, section 1921.73a – Ecosystem Diversity).

Recently, in response to climate change, some sources suggest that historical range of variability is no longer a relevant concept (deBuys 2008, Fulé 2008), that it should be abandoned altogether, or perhaps it should be replaced with 'future range of variability' (Duncan et al. 2010). [Note that this issue of RV and climate change is discussed at length in this white paper, beginning on page 14.]

This white paper is designed to address six objectives:

1. Provide background and context explaining how an RV approach has been used in the Pacific Northwest Region of the U.S. Forest Service.
2. Describe certain concepts and principles related to the range of variation.
3. Describe how RV can support Forest Service project planning processes.
4. Provide ranges of variation for species composition, forest structure, stand density, and certain other ecosystem components (ranges are expressed as percentages and presented in a table for each component).
5. Provide a glossary of terms related to the RV concept.
6. Provide references and literature citations pertaining to the range of variation.

BACKGROUND AND CONTEXT FOR THIS WHITE PAPER

A report, "Restoring Ecosystems in the Blue Mountains: A Report to the Regional Forester and the Forest Supervisors of the Blue Mountains" (Caraher et al. 1992), was released in July 1992. This document, often referred to as the Caraher Report, was prepared by a panel of scientists who used nine indicators to assess ecosystem restoration needs for the Blue Mountains.

The Caraher Report probably provided the first Pacific Northwest example of how a concept called the historical range of variability (HRV) could be applied. The Northern Region of the Forest Service initially incorporated the HRV concept in their Sustaining Ecological Systems (SES) process (USDA Forest Service 1992); the Caraher panel adopted HRV and other SES principles for their Blue Mountains restoration assessment.

In March 1993, Natural Resources Defense Council (NRDC) petitioned the Pacific Northwest Region of the U.S. Forest Service to halt all timber harvest activity in old growth forests on national forest lands located east of the Cascade Mountains crest in Oregon and Washington (this geographical area is traditionally referred to as the Eastside).

A month later in April 1993, a group of university and U.S. Forest Service research scientists released an "Eastside Forest Ecosystem Health Assessment;" this assessment is known as the Everett Report because it was directed by Dr. Richard Everett (Everett et al. 1994).[2]

In response to the NRDC petition and Everett report, U.S. Forest Service Regional Forester John Lowe issued interim direction in August 1993 requiring that timber sales prepared and offered by Eastside national forests be evaluated to determine their potential impact on riparian habitat, historical vegetation patterns, and wildlife fragmentation and connectivity.

This interim direction, known as the Eastside Screens, was used to amend Eastside forest plans when Regional Forester John Lowe signed a Decision Notice on May 20, 1994 to implement Regional Forester's Forest Plan Amendment #1 (USDA Forest Service 1994). A slightly revised version of the Eastside Screens was issued as Regional Forester's Forest Plan Amendment #2 when Lowe signed a Decision Notice on June 12, 1995 (USDA Forest Service 1995).

[2] The Everett Report was prepared in response to a May 1992 request from U.S. House Speaker Tom Foley and U.S. Senator Mark Hatfield for a scientific evaluation of effects of USDA Forest Service management practices on sustainability of forest ecosystems in eastern Oregon and eastern Washington. Over 100 scientists worked for more than a year on the assessment; results were published as a series of general technical reports by the Pacific Northwest Research Station in 1994 and 1995.

The Screens' ecosystem standard requires a landscape-level assessment of the historical range of variability[3] for forest structural stages, including a determination of how existing structural stage percentages compare with their historical ranges.

To my knowledge, the Eastside Screens are the first instance of the RV approach being used as a mandatory requirement for land and resource management planning. And, I believe the RV concept is well suited for this role.

CONCEPTS AND PRINCIPLES RELATED TO RV

The RV concept is used to characterize fluctuations in ecosystem conditions and processes over a time period (fig. 1). We now understand that ecosystem conditions change as disturbance processes affect them; disturbances historically acted with a relatively consistent frequency and intensity (severity), and ecosystems responded to this certainty by exhibiting a predictable behavior and level of complexity (Aplet and Keeton 1999, Morgan et al. 1994).

Figure 1 demonstrates that effects of repeated disturbance events cause conditions to fluctuate between upper and lower limits, suggesting that nature does not function with perfect replication from one disturbance event to another.

Assume the trend line in figure 1 shows fluctuations in old forest structure within a watershed. Over time as stands mature, old-forest acreage increases toward an upper limit until a disturbance process eventually transforms some of it into another structural stage, at which point the old-forest acreage declines toward a lower limit.

Fine-scale disturbance processes such as root disease cause small reductions in old-forest acreage; broad-scale processes such as crown fire or bark beetle outbreaks may result in dramatic old-forest declines. In the hypothetical example portrayed in figure 1, ecosystem dynamics produced by disturbance processes describe a range of variation for old-forest structure.

As a concept, RV recognizes that ecosystem components have a range of conditions in which they are resilient and self-sustaining, and beyond which they move into a state of disequilibrium (Egan and Howell 2001, Holling and Meffe 1996).

If an ecosystem component declines to a point that never occurred historically, it is assumed that natural processes alone will not be able to recover or sustain this component in the future (USDA Forest Service 1992).

Holling and Meffe (1996) expressed this concept well when they noted that "management should strive to retain critical types and ranges of natural variation in resource systems in order to maintain their resiliency."

[3] Historical range of variability (HRV) and range of variation (RV) are used somewhat interchangeably in this white paper. HRV has long tenure, dating back to the early 1990s, but the Forest Service recently adopted RV as its term of choice for describing variability of reference conditions (see FSH 1909.12, section 43.13). For this white paper, HRV and RV are considered to be equivalent terms.

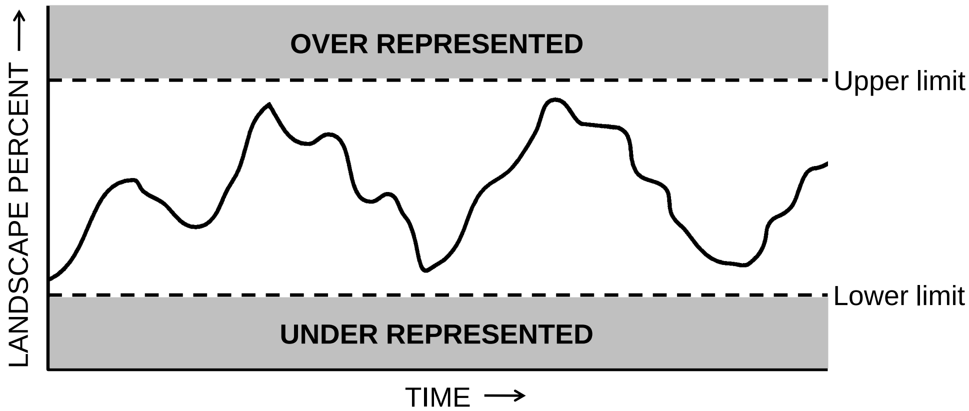


Figure 1 – A range of variation (RV) helps us decide whether existing amounts of vegetation composition, structure, and density, when summarized for a landscape-scale analysis area, occur within a characteristic range (Aplet and Keeton 1999, Morgan et al. 1994, Swanson et al. 1994). This diagram shows an ecological trajectory of an ecosystem component (solid line) varying through time because the phrase 'range of variation' is meant to encompass more than just the extreme values (upper and lower limits shown as dashed lines) (diagram was modified from Morgan et al. 1994).

RV is a good example of the dynamic equilibrium concept because modal or central-tendency conditions obviously vary over time (shown by squiggly solid line in center), and yet they vary within an equilibrium zone whose limits (dashed lines) are confined within a range of potential ecological expressions. Note that conditions occurring above the upper limit are considered to be over-represented; conditions below the lower limit are considered to be under-represented (the representation zones are gray).

RV is an analytical technique to characterize inherent variation in species composition, forest structure, and stand density, reflecting recent evolutionary history and dynamic interplay of biotic and abiotic factors. "Study of past ecosystem behavior can provide the framework for understanding the structure and behavior of contemporary ecosystems and is the basis for predicting future conditions" (Morgan et al. 1994).

RV is meant to reflect ecosystem properties free of major influence by Euro-American humans, providing insights into ecosystem resilience (Kaufmann et al. 1994, Landres et al. 1999).

RV helps us understand what an ecosystem is capable of, how historical disturbance regimes functioned, and inherent variation in ecosystem conditions and processes – patterns, connectivity, seral stages, and cover types produced by ecological systems at a landscape scale (USDA Forest Service 1997).

ECOSYSTEM VARIATION AS A FOUNDATION FOR RV

RV is not intended to portray a static, unchanging condition. Ecosystems of the interior Pacific Northwest evolved with a steady diet of wildfire, insect outbreaks, disease epidemics, floods, landslides, human uses, and weather cycles. Change was, and still is, the only constant in their development.

RV is designed to characterize a range of vegetation composition, structure, and density produced by disturbance processes – these important and ecologically influential agents of change (Morgan et al. 1994).

An early generation of American ecologists was led at the start of the twentieth century by Nebraska scientist Frederic Clements. Clements and his University of Nebraska collaborators (particularly Charles Bessey and Rosco Pound) believed that plant succession caused ecosystems to develop in a predictable sequence of steps – much as a human infant matures into an adult. Proponents of this super-organism philosophy maintained that individual species were linked together in mutually beneficial systems exhibiting properties greater than the sum of their parts (Clements 1916, Egerton 1973, Wu and Loucks 1995).

Clements contended that nature was orderly, and that its order was, for the most part, stable and self-regulating. He assumed that the normal condition of ecosystems was a state of homeostasis or equilibrium – a forest grows to a mature climax stage, which becomes its naturally permanent condition (Clements 1916). Many contemporary ideas about the environment are based on Clements' notion that nature can retain its inherent balance more or less indefinitely if only humans could avoid disturbing it (Cronon 1996, Shugart and West 1981).

Contrary to Clements' claims, later work showed that nature's normal state is not one of balance – a normal situation is to be recovering from the last disturbance. Change and turmoil, rather than constancy and balance, seems to be the rule. We now know that the concept of a forest evolving to a stable (climax) stage, which then becomes its naturally permanent condition, is incorrect (Botkin 1990, Stevens 1990).

In many areas, and particularly in the interior Pacific Northwest, large-scale disturbances are common, and development to a truly stable climax is rare or absent (Kipfmuller et al. 2005, O'Hara and others 1996).

"As Clementsian climax theory fell out of favor, ecologists increasingly resorted to concepts such as the historical range of variability to bound their understanding of a system's innate potential. But for HRV to have utility, the range of variability must have reasonably fixed boundaries, which are largely determined by climate and edaphic factors. When climate changes substantially, the boundaries can weaken, and ranges of variability can wobble off course" (deBuys 2008).

Historical ecology can teach us what worked and what lasted – how resilient ecosystems sustained themselves through time (Swetnam et al. 1999). The type and frequency of presettlement disturbances can serve as a management template for maintaining sites within their historical range of plant composition and vegetation structures – if landscapes can be maintained within RV, then they stand a good chance of maintaining their biological diversity and ecological integrity through time (Aplet and Keeton 1999, Holling and Meffe 1996).

An RV approach ensures that management activities are consistent with conditions under which native species, gene pools, communities, landscapes, and ecosystem processes evolved (DeLong and Tanner 1996). It is typically assumed that presettlement conditions represent optimum habitats for native plants and animals, and that the best way to recover an endangered or threatened species is to restore its habitat to some semblance of presettlement conditions (Botkin 1995).

Since a key premise of RV is that native species have evolved with, and are adapted to, the historical disturbance regimes of an area, ecosystem components occurring within their historical range are believed to represent sustainable conditions (Aplet and Keeton 1999, Swanson et al. 1994).

At a landscape scale, for example, a forest might be considered healthy and sustainable if spatial and temporal patterns of its composition, structure, and density are within a range of variation.

RV is used as a tool to help us understand present forests and why they respond as they do when exposed to management practices – it uses the past to help us understand the present, to understand which forces affect vegetation response, to gain insight into possible trajectories of future forests, and to integrate this information when proposing management alternatives (Millar and Woolfenden 1999).

RV AS A PLANNING TOOL[4]

Beginning in the early 1990s, a long-standing debate intensified about the purpose of national forests and their contribution to American society. This debate demonstrates that certain segments of American society prefer federal forests to function primarily as old-growth reserves, or to provide essential wildlife habitat. Other Americans believe that public wildlands should offer recreational opportunities as their primary purpose, whereas some feel they should be managed to supply commodities such as timber, livestock forage, minerals, and water.

The purposes for which national forests are managed are broadly established in federal law, and then refined for each individual unit through a planning process incorporating public input. But the goals and objectives for which a national forest is to be managed cannot be exclusively a matter of public (societal) preference.

Biophysical factors dictate a range of ecosystem states that are possible for an area, historical factors such as wildfire and timber harvest determine what is present there now, and both sets of factors ultimately control societal choices available at any point in time (fig. 2).

Forests adapted to a dry temperate climatic regime, for example, cannot be made to take on the characteristics of moist tropical forests, even if they are highly desired by society – in this instance, the biophysical site potential would obviously trump societal desires.

A good example of the biophysical potential concept is provided by the open and parklike forests historically created and maintained by surface fire (fig. 3). On warm dry sites such as those in figure 3, an historical process (frequent surface fire) maintained large, widely-spaced, fire-tolerant trees over an undergrowth so free of brush and small trees that settlers could often drive their wagons through the forest as if it was a carefully manicured park (Evans 1991, Munger 1917).

[4] This section describes RV for broad-scale planning. For a detailed discussion about RV and fine-scale planning, refer to a section called "Project Planning and RV" later in this paper (page 19).

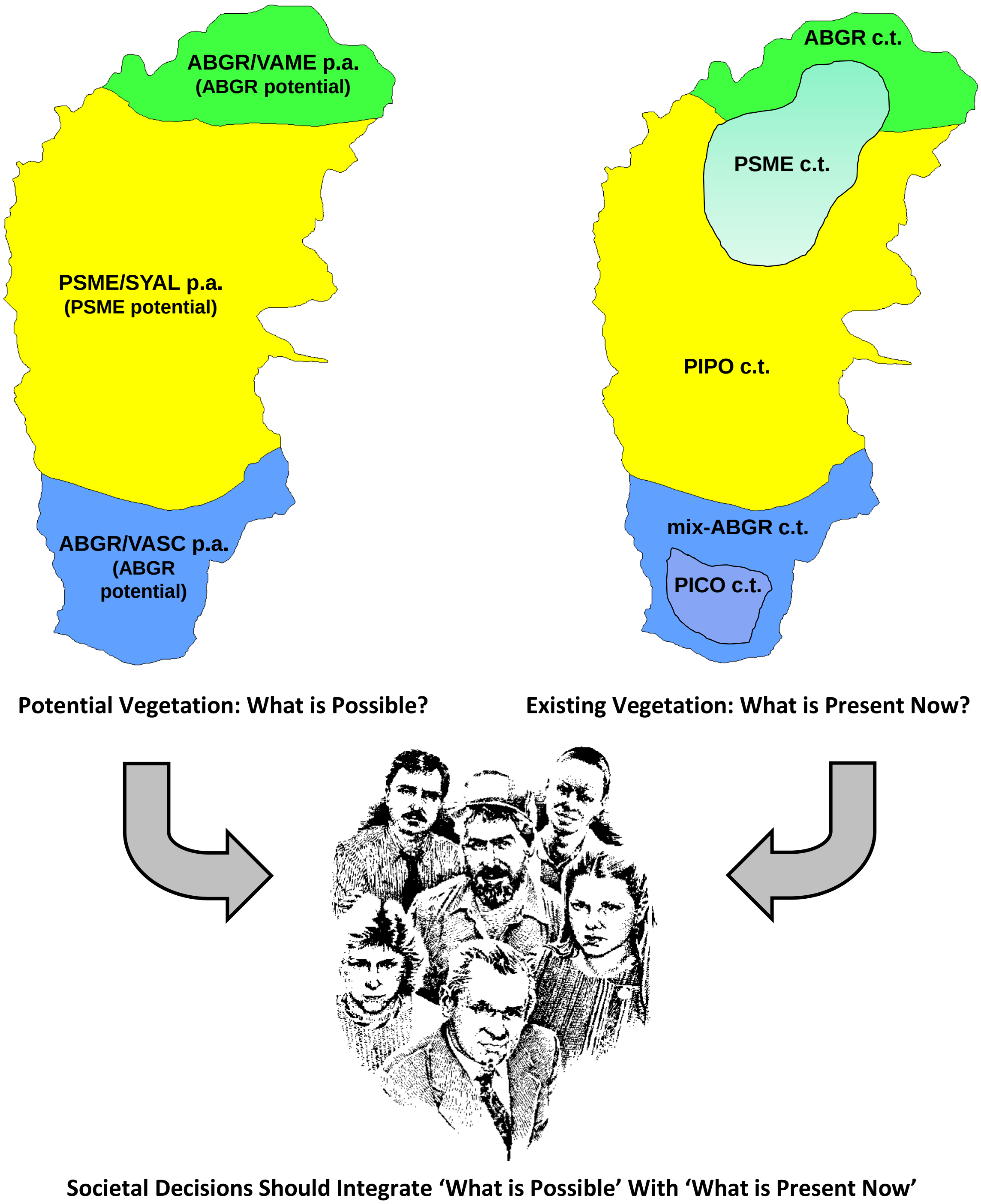


Figure 2 – Developing desired conditions for land management planning is a societal process. RV should not be used as a desired condition (Millar 2014), but it can function as a baseline to help society understand biophysical potential of ecosystems (upper left, showing three plant associations (p.a.) and their tree species potential: ABGR is grand fir; PSME is Douglas-fir; PIPO is ponderosa pine; PICO is lodgepole pine).

After establishing a biophysical template, existing conditions for composition (upper right; c.t. is cover type), structure, density, and other ecosystem components can be compared with reference conditions (the Range of Variation).

Using RV in a manner described here could help society agree on a set of desired conditions by integrating potential vegetation (what is possible) with existing vegetation (what is present now).

Figure 3 – Open ponderosa pine forest with herbaceous undergrowth (stand of old-growth *Pinus ponderosa* near Whitney, Oregon, ca. 1900 [J.W. Cowden]; courtesy Gary Dielman, Baker City library). Pioneer journals (Evans 1991), early surveys (Gannett 1902, Munger 1917), and fire history studies (Heyerdahl 1997, Maruoka 1994) suggest that many Blue Mountains dry-forest sites had presettlement conditions resembling this image, particularly for Douglas-fir/pinegrass and grand fir/pinegrass plant associations (Weaver 1967). A combination of a warm dry temperature-moisture regime and a disturbance regime featuring frequent surface fire created the distinctive composition and structure shown here. Some studies concluded that this ecosystem condition reflects a long-term cultural practice because traditional human uses (Native American burning and associated plant species utilization) were important for sustaining the biodiversity and productivity of these ecological settings (Boyd 1999, Vale 2002).

By disrupting the short-interval fire regime on dry sites, society unintentionally decided to replace an open, parklike condition with a dense, multi-layered structure. It is possible for dense forest to exist on warm dry biophysical environments, but only at a high potential cost in terms of future susceptibility to uncharacteristic fire effects and insect or disease impact (Agee 1994, Hessburg et al. 1994, Huff et al. 1995, Lehmkuhl et al. 1994, Mutch et al. 1993, Wickman 1992).

And, if land management policy continues to emphasize systematic fire exclusion for dry-forest sites, society should acknowledge that when fire returns to them, as it inevitably will, our socio-economic systems and associated infrastructure must be willing and prepared to accept the consequences of an exclusion policy, including attendant side effects of uncharacteristic fire behavior and undesirable fire effects.

It is likely "that the high costs and consequences of excluding necessary ecological processes (e.g., fire) will soon shape human desires and decisions more than they have in the past" (Swetnam et al. 1999). Now that large fires are occurring at an unprecedented rate (Bennett 2000), consuming steadily increasing proportions of the Forest Service's annual budget allocation and transferring project-level funds away from resource management functions and into fire suppression accounts, it appears that the "high costs and consequences" of fire suppression are finally being realized at the federal government level (GAO 1999).

When considering that dense, dry-site forests have existed for more than a half-century in many portions of the western United States, society is now faced with an interesting dilemma:

- If the current cohort of natural resource managers has grown accustomed to dense, mixed-species forests on dry sites, perhaps now accepting them as 'normal' and assuming they can be perpetuated into the future;
- Then society must acknowledge that if we can successfully restore a short-interval fire regime and its historically open stand density, these conditions will be ill suited for providing wood, elk cover, and many other services that society has come to expect from <u>dense</u> dry forests (Gruell 2001, Moore et al. 1999).

In contrast to the dry-forest situation, forests with a moist biophysical potential cannot be sustained in a parklike condition without constant tending from activities such as timber harvest or biomass removal. The biophysical factors influencing moist environments would allow some of them to be maintained in a parklike condition if this is society's objective, but only with substantial human intervention because the native disturbance regime created little or none of this condition on its own (and never across substantial acreages).

These examples are designed to demonstrate that society must first strive to learn what a normal or characteristic 'state of being' is for an ecosystem type (in the context of biophysical potential and associated ranges of variation), and then use this knowledge to inform natural resource policy and decision making (fig. 2).

A fundamental tenet for hierarchical analysis during planning is: at whatever scale planning is occurring, look up one level to obtain context, and look down one level to understand process (Haynes et al. 1996, O'Neill et al. 1986). As an example of hierarchical analysis, let's say that a range of variation (RV) analysis has identified a watershed as a candidate for harvest of old forest structure because it is currently 'above RV' with respect to this structural stage (i.e., old forest abundance exceeds the upper limit of RV – see fig. 1).

Continuing with this example, however, it would be important to evaluate RV at the next highest hierarchical level (subbasin scale in this example) because without such information, an analyst would be unaware of the watershed's contribution to old-forest structure in a subbasin context – and such knowledge might have an important influence on a tree harvest decision-making process.

If it turns out that the subbasin also exceeds RV for old-forest structure, or if it occurs within the range but near the upper limit, then targeting the watershed for tree harvest might be an appropriate and reasonable approach. On the other hand, if the subbasin is below RV for old-forest structure, then deferring tree harvest in the watershed may be prudent until old forest abundance at the subbasin scale is restored to an ecologically appropriate level.

This same approach can be used through all hierarchical levels – RV could be assessed at a broad scale first, then stepped down to the next lowest level, reassessed, and so on down to the site or stand level. It can also be used with a full suite of ecosystem components or categories of interest – a forest landscape in synchrony with RV would not only provide old forest at an appropriate abundance and configuration, but it would also contain young and mid-age patches with size, shape, composition, and structure all occurring within RV for these ecosystem elements (Aplet and Keeton 1999, Morgan et al. 1994).

When we think about scale, a spatial example typically comes to mind. But temporal scales are also important. The time scales associated with landscape pattern and structure range from years to centuries, but variations in stream flow or bank structure can sometimes be measured in days, and biome-level changes may span millennia. Forest vegetation often requires hundreds of years to develop to its full expression, and erosion processes frequently span thousands of years (Eng 1998).

An appropriate temporal perspective is important because "how can human communities manage landscape change that takes place over a hundred years or more, when people's perceptions and priorities change from generation to generation, or even from election to election?

Humans may not have the right 'attention span' to manage environmental change, and this may be the species' fatal flaw. Perhaps this is the value of history – as an attempt to extend the time frame of our memory beyond the human lifetime. The only problem is that history represents selective memory" (Spirn 1996).

RV AS A BASELINE

RV can appropriately serve as a baseline from which change can be measured; it is not designed to provide a specific condition for active restoration purposes, although RV could provide a useful framework for evaluating restoration alternatives (USDA Forest Service 1997). [But also note that collaborative or consensus groups are often interested in using presettlement conditions as a restoration objective (Christopherson et al. 1996)].

A common misconception is that it might be appropriate to use RV as a management objective by linking desired conditions directly to RV (Millar 2014), but a better approach is to let reference conditions and historical data inform an analyst about the potential behavior and expected consequences of restoration treatments (Millar 1997).

"If ecosystems are necessarily dynamic, then it may be misguided and fruitless to choose a single fixed point or period of time in the past for establishing a static, desired future condition" (Sprugel 1991, Swetnam et al. 1999).

Not only is selecting a single temporal point inconsistent with the RV concept (Powell 2000), but choosing a single target condition (e.g., "50% of dry-forest sites should occur in the old forest single stratum (OFSS) structural stage") is also a misguided strategy because a range of conditions better reflects a dynamic equilibrium (e.g., "30-70% of dry-forest sites should occur in the OFSS stage").

Helping to identify opportunities to restore an ecosystem's resilience and integrity – its capacity for regeneration and renewal – is perhaps the most important contribution that RV information can offer to an assessment or planning effort. But this recommendation presumes that past conditions and processes, as reflected by RV, provide appropriate context and guidance for management of contemporary ecological systems (Landres et al. 1999).

Even if land managers wish to turn the clock back to some nostalgic preconception of the presettlement era, our current reality of dams, roads, cities, fire suppression, climate change, and escalating human demands on natural resources would render this goal problematic.

Clearly, we cannot turn our wheat fields back into properly functioning bluebunch wheatgrass steppes, no matter how inadequate they might now seem. We simply cannot go back in time and undo all that has happened and, in this sense at least, we are prisoners of our own history (Worster 1996).

A recent scientific assessment for the interior Columbia River basin suggests it would be difficult, if not impossible, to restore presettlement conditions for many portions of the western United States, even if society adopted this as an explicit policy objective (Quigley and Arbelbide 1997).

WHAT TIME PERIOD SHOULD RV REPRESENT?

Human history is dwarfed when compared with the Earth's geological history. When considering the vast changes occurring over geologic time, ecological history seems inconsequential. But ecosystems do change, albeit slowly. Some vegetation changes are so difficult for people to recognize that they have been referred to as an 'invisible present' (Magnuson 1990), evoking a perception of forest tranquility due to the seemingly timeless nature of large trees (Shugart and West 1981).

As commonly used in the interior Pacific Northwest, RV refers to a range of reference conditions existing prior to Euro-American emigration (the 'presettlement' era). The Eastside Screens states that "the HRV should be based on conditions in the presettlement era" (USDA Forest Service 1995).

For the Blue Mountains, a presettlement timeframe is defined as early to mid-1800s because it coincides with an Oregon Trail era when Euro-American influences began (Evans 1991). It is also well aligned with contemporary climatic conditions, which have been in place for about 2,700 years (Mack et al. 1983).

The temporal baseline for which ranges are pertinent should be selected carefully to ensure it reflects presettlement conditions. This decision is easier for the western

United States than for other areas because the West was settled relatively recently. In the British Isles, for example, the shieling system was a kind of mixed agriculture practiced in Scotland from prior to 1000 AD to the late 1700s, when it was largely abandoned due to poor harvests, famine, bouts of human disease, and a variety of other factors. Currently, only the occasional stone wall or drainage ditch provides clues that a widespread and relatively persistent pastoral society once existed in areas managed under the shieling system (Holl and Smith 2007).

The Holl and Smith (2007) study provides a good example of potential pitfalls associated with establishing a temporal baseline for RV analyses. Any attempt to base historical ranges on conditions existing on Scotland's moors in the mid-1800s would need to account for the persistent ecological effects of a long-term human influence reaching back almost a thousand years (the shieling system). Otherwise, it is likely that RV ranges would not reflect 'pristine' (non-anthropogenic) conditions if this were an explicit objective of adopting the RV concept (Holl and Smith 2007).

RV AND CLIMATE CHANGE: IS THE PAST ALSO A PROLOGUE FOR THE FUTURE? (NO!)

Substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and temperature (Milly et al. 2008). "Climate change suggests that planning must not depend on expectations that the past will provide a template for the future. But if not the past, then what? For the present, no one seems to know. Like the often-quoted investment advice, it now seems that past performance is no guarantee of future results" (deBuys 2008).

In a climate change context, a big concern with RV is that it is an approach looking back – as if the past, instead of the future, will be used to guide management.

Some people believe that a presettlement era, overlapping with a period called the Little Ice Age (1300-1850) (Fagan 2002), should no longer be used as a reference baseline because future conditions could be much warmer and drier than the mid-1800s due to climate change.

Recent efforts to map changes in biophysical regimes for the United States, for example, found that half of the area could have shifts in moisture, temperature, and soil conditions such that it would be difficult to sustain 'historic' (presettlement) ecosystems there (Harris et al. 2006, Saxon et al. 2005).

Continuing with an RV approach, however, may still be appropriate, as described here: "Some feel that HRV may no longer be a viable concept for managing lands in the future because of expected climate warming and increasing human activities across the landscape. Today's climates might change so rapidly and dramatically that future climates will no longer be similar to those climates that created past conditions. Climate warming is expected to trigger major changes in disturbance processes, plant and animal species dynamics, and hydrological responses to create new plant communities and alter landscapes that may be quite different from historical analogs" (Keane et al. 2009:1033-1034).

“At first glance, it may seem obvious that using historical references may no longer be reasonable in this rapidly changing world. However, a critical evaluation of possible alternatives may indicate that HRV, with all its faults and limitations, might be the most viable approach for the near-term because it has the least amount of uncertainty” (Keane et al. 2009:1034), particularly when compared with uncertainty associated with magnitude, timing, scale, and spatial extent of climate change impacts.

“Given the uncertainties in predicting climatic responses to increasing CO_2 and the ecological effects of this response, we feel that HRV time series derived from the past may have significantly lower uncertainty than any simulated predictions for the future. We suggest it may be prudent to wait until simulation technology has improved to include credible pattern and process interactions with regional climate dynamics and there has been significant model validation before we throw out the concept and application of HRV. In the meantime, it is doubtful that the use of HRV to guide management efforts will result in inappropriate activities considering the large genetic variation in most species and the robustness inherent in regional landscapes that display the broad range of conditions inherent in HRV projections” (Keane et al. 2009:1034).

“Historical reference conditions remain useful to guide management because forests were historically resilient to drought, insects, pathogens, and severe wildfire. Adaptation of reference information to future climates is logical: historical characteristics from lower, southerly, and drier sites may be increasingly relevant to higher, northerly, and currently wetter sites” (Fulé 2008).

“The study of past forest change provides a necessary historical context for evaluating the outcome of human-induced climate change and biological invasions. Retrospective analyses based on fossil and genetic data greatly advance our understanding of tree colonization, adaptation, and extinction in response to past climatic change” (Petit et al. 2008).

This section demonstrates that although the RV approach has recently been questioned, especially in a climate change context, it is believed to function as a useful tool for informing management practices, rather than being used to set firm targets (Thompson et al. 2009) – RV is still useful for understanding the past in order to help manage ecosystems properly in the future (Swetnam et al. 1999).

It also illustrates the importance of establishing a relevant reference period, which is the time period or era used to estimate the range of variation under historic disturbance regimes, including indigenous (American Indian) influences.

If using a historical reference period is problematic in a climate change context, then how might the RV concept be adapted to perhaps function as a ‘future range of variation’ (FRV)? A forward-looking FRV framed to be consistent with future, warming-induced reductions in snowpack, leading in turn to increased drought stress, reduced tree growth and survival, increased occurrence of wildfire, insects, and diseases, and changed forest composition and structure (Boag et al. 2018)?

Three possible strategies for adapting RV concepts to be more compatible with future climate change (i.e., formulating an FRV) could be considered:

1. When completing an RV analysis for a biophysical environment, use RV ranges for one class warmer and dryer than the class being analyzed (Hessburg et al. 2013). This strategy is compatible with analyses involving relatively detailed stratifications (item #3 in "Project Planning and RV" discusses stratification).

   This strategy is inappropriate for analyses utilizing potential vegetation groups (PVGs) because PVGs are too coarse to drop down by one whole class (it would not be appropriate to use Dry UF ranges for Moist UF acreage, or Moist UF ranges for Cold UF acreage). But if an RV analysis is completed at a plant association group (PAG) level, then this strategy might very well be appropriate (use Hot Dry UF ranges for Warm Dry UF acreage occurring in an analysis area).
2. Use existing RV ranges as a start-point, but then estimate departure from these initial conditions in response to climate change. Adopting this approach typically involves shifts in ranges for a stratification class. If an RV range for ponderosa pine on Dry UF sites is 50-80% (table 3), and if this biophysical environment is expected to be warmer and dryer in the future, then a ponderosa pine range might be modified to 60-90% to reflect increased habitat for ponderosa pine under future climates (or, a range of 40-90% might be adopted to acknowledge that future climates may also be more variable than at present, so a range could be wider to account for vegetation conditions associated with increased variation).
3. Use state-and-transition modeling to prepare new RV ranges. This strategy requires estimates of future abundance and representation of upland forest composition, structure, and density classes (perhaps these estimates could be derived from FVS-Climate modeling?), and then loading revised values into a state-and-transition model such as VDDT (see fig. 7, later). State-and-transition simulations could be completed to derive new RV ranges for each analysis category (e.g., the composition, structure, and density classes).

What might help you decide which of these three strategies makes the most sense for your circumstances? I believe a logical first step in a decision-making process involves evaluating magnitude and timing of future Blue Mountains climate change. How severe will climate changes be, and when are they expected to occur? Will a transition from contemporary climates be gradual, or abrupt? And, how will future climates affect disturbance regimes like wildfire or insects and diseases?

For the Blue Mountains, we are fortunate because answers for questions like these can be obtained from place-based research studies. Good sources for examining future Blue Mountain climates, and their effects, include: Boag et al. 2016, 2018; Clifton et al. 2018; Dwire et al. 2018; Halofsky and Peterson 2017; Halofsky et al. 2018; Hamilton et al. 2015a, 2015b, 2015c, 2016; Hartter et al. 2017, 2018; Kerns et al. 2018; Kim et al. 2018; and Peterson and Halofsky 2018.

ECOSYSTEM COMPONENTS ASSOCIATED WITH AN RV ANALYSIS

Vegetation integrates ecosystem components called composition, structure, and process (function); ecosystem components occur as multi-level hierarchies (table 1).

Composition refers to relative abundance of ecosystem components such as water, nutrients, and species. Structure refers to physical arrangement of composition, and function refers to processes through which composition and structure interact, including predation, decomposition, and disturbances such as fire (Aplet and Keeton 1999).

Species Composition

Composition refers to kinds and numbers of organisms composing an ecosystem (Manley et al. 1995). Depending on the hierarchical level being considered, forest composition includes individual trees, aggregations of tree species called cover types, or combinations of cover types called life forms (table 1).

Table 1: Examples of forest ecosystem components, presented for three hierarchical levels.

	ECOSYSTEM SCALE (HIERARCHICAL LEVEL)		
COMPONENTS	FINE	MID	BROAD
Composition	Individual tree	Cover type	Lifeform (tree/shrub/herb)
Structure	Tree size class	Structural stage	Physiognomic class
Process/Function	Photosynthesis	Disturbance	Climate

Sources/Notes: Although they are shown individually in this table, ecosystem components are interrelated – from an ecological perspective, they do not operate independently.

Forest Structure

Structure includes physical arrangement or spatial distribution of ecosystem composition (Manley et al. 1995). Structure occurs both horizontally (spatial distribution of structure classes across an area) and vertically (trees of varying height growing in a multi-layered arrangement). Depending on the hierarchical level being considered, examples of forest structure include size classes, structural stages, or physiognomic classes (table 1).

Process/Function

Processes involve flow or cycling of energy, materials, and nutrients through space and time (Manley et al. 1995). Forest processes include everything from photosynthesis and nutrient cycling to stand-initiating wildfires and climatic cycles (table 1).

In the interior Pacific Northwest, disturbance processes have influenced forest vegetation conditions to a greater degree than other ecosystem processes (Clark and Sampson 1995, O'Hara et al. 1996, Oliver and Larson 1996).

Processes have an important influence on species diversity. Recent studies of British plants and birds found that different processes are likely to determine species diversity (biodiversity) at different spatial scales, and that the species richness pattern at a fine scale was statistically unrelated to the pattern at a coarse scale (Whittaker et al. 2001, Willis and Whittaker 2002).

CONDUCTING AN RV ANALYSIS

Apparently, there is no limit to the number of ecosystem characteristics that could be assessed by using the range of variation concept – Manley et al. (1995) identified more than 36 such characteristics, including features like cobble embeddedness, and, in theory at least, all pertinent ecosystem metrics could be assessed and interpreted by using an RV approach (Egan and Howell 2001).

Broad-scale assessments completed for the Blue Mountains physiographic province and the interior Columbia River basin suggest that upland forest ecosystems could be characterized as healthy, sustainable, and resilient if three of their ecosystem components – species composition, forest structure, and stand density – are within RV (Caraher et al. 1992; Gast et al. 1991; Lehmkuhl et al. 1994; Quigley et al. 1996; USDA Forest Service 2002).

It is recommended that an RV analysis for upland-forest biophysical environments include at least three ecosystem components: species composition, forest structure, and stand density.

RV results are typically presented for an entire analysis area, but they can also be reported for subdivisions (such as combinations of subwatersheds) when an analysis area is especially large. Subdivisions of a large watershed (fifth code hydrologic unit) or a subbasin (fourth code hydrologic unit) might be especially useful for supporting fine-scale project planning efforts.

Subdividing an RV analysis area into smaller units must be done carefully. Some areas have a strong elevational gradient resulting in equivalent proportions of biophysical environments (Desolation Creek watershed on the North Fork John Day Ranger District is an example of this situation).

Caution: If not done carefully, subdividing areas with similar proportions of biophysical environments can essentially disrupt their equivalence ('balance'), resulting in inconsequential or minor amounts of one or more biophysical environments. If subdivision is attempted and this outcome happens, it might be advisable to conduct an RV analysis for the whole area as one integrated analysis area.

Results of an RV analysis are generally presented in a table showing existing percentages and RV percentages for each ecosystem component, and stratified by using categories of potential vegetation such as potential vegetation groups (PVG).

The next section, *Project Planning and RV*, provides detailed information about an analytical, step-wise process for conducting an RV analysis in support of landscape-level project planning.

Establishing large, landscape-scale analysis areas (such as those comprising 30,000 acres or more) is a common strategy for timber sales and fuels reduction projects, although these multi-year planning processes generally feature an integrated suite of natural resource project work (not just a timber sale or fuels project).

Project Planning and RV

When a vegetation management project is proposed for implementation on National Forest System lands, an interdisciplinary planning process must be completed before any ground-disturbing activities can occur. When a proposed project involves modifications to an area's existing complement of vegetation cover types, forest structural stages, or stand density classes, then:

- A planning process should include an RV analysis (according to a Forest Plan amendment referred to as Eastside Screens, an RV analysis <u>must</u> be considered for forest structural stages if a proposed project includes a timber sale).
- Documentation should disclose how RV results were used to identify which cover types, structural stages, or density classes are proposed for treatment.

This section provides a primer about fundamental vegetation planning concepts and principles. An RV analysis will typically be completed at several points in a vegetation planning process; this section identifies when those points occur, and it provides my thoughts about incorporating RV analysis into the overall project planning process for integrated vegetation treatments.

Cautions and caveats: This section provides my perspectives as a vegetation manager and silviculturist – I am neither an environmental coordinator nor a NEPA expert. These perspectives describe my experience, as a resource specialist on IDTs, with integrating vegetation management considerations, including utilization of RV as an analytical technique, into an overall project planning (NEPA) process.

1. **Before initiating a planning process, an analyst should develop an understanding of reference conditions for ecosystem components in a planning area** (e.g., soil conditions, animal population sizes, plant species or seral stage composition, stream sediment loads, air quality, forest structural stages, etc.). Developing an awareness of reference conditions is best accomplished by consulting historical data sources, particularly maps depicting species composition, forest structure, stand density, and disturbance events.
   (a) Umatilla National Forest made significant investments over prior 20 years to locate and digitize relevant historical mapping, including maps derived from General Land Office survey notes collected in 1880s (Powell 2019c); thematic maps depicting forest conditions in 1900, 1914-16, 1935-36, 1953-60, and 1987-88 (Powell 2019b); and topical maps portraying wildfires, insect outbreaks, and other disturbance processes (Powell 2012b, 2019b). Disturbance mapping is particularly valuable for understanding fundamental ecological processes influencing forest composition, structure, and density.

2. **Use an appropriate size of planning (analysis) area**.
   (a) It is recommended that an RV analysis be conducted for land areas no smaller than 15,000 to 35,000 acres (this recommended size range was taken from May 1994 Environmental Assessment for Eastside Screens: see USDA Forest Service 1994).

(b) Areas larger than 35,000 acres are appropriate and preferable for an RV analysis; areas smaller than 15,000 acres should be avoided since vegetation patterns might not be consistent with those created by historical disturbance regimes of an analysis area (also from USDA Forest Service 1994).

(c) Fire Regime Condition Class (FRCC) assessment system (Barrett et al. 2010) is used to characterize fire regimes and understand their departure from historical reference conditions. FRCC uses many of the same concepts as range of variation (fig. 4). Pacific Northwest Regional Office (R.O.) provided FRCC scale recommendations based on grain (resolution) considerations related to typical patch-size variation by fire regime group. Here are the R.O.'s recommendations by hydrologic unit code:

Fire Regime Group	Suggested Analysis Unit (HUC)
I/II (Low/mixed severity)	HUC6 (subwatershed)
III (Mixed/low severity)	HUC5 (watershed)
IV/V (Replacement severity)	HUC4 (subbasin)

3. **Stratify vegetation data into potential vegetation groups**.

(a) An RV analysis relies on a consistent stratification of potential vegetation. Before conducting an RV analysis, planning area acreage should be stratified into potential vegetation groups (PVG)[5]. Generally, potential vegetation type (ecoclass) codes are available for vegetation polygons in an analysis database, and a cross-walk process can be used to assign PVG by using ecoclass codes (a good example of a cross-walk table is appendix 1 of this white paper; tables 8-9 in Powell et al. 2007 also function well as PVT to PVG cross-walk tables).

(b) PVG information for Blue Mountains is provided in a report: "Potential vegetation hierarchies for the Blue Mountains section of northeastern Oregon, southeastern Washington, and west-central Idaho" (Powell et al. 2007). Copies of this report are available from a Pacific Northwest Research Station website (http://www.treesearch.fs.fed.us/pubs/27598).

(c) **If less than 1,000 acres of a PVG occurs in a planning area, it should be ignored during analysis** because a full complement of cover types, structural stages, or density classes would not be expected for such a small acreage. If a PVG has less than 1,000 acres in a planning area, do not add it to another PVG because it is not appropriate to combine ecosystem components (cover types, structural stages, density classes) produced by different disturbance regimes (at a broad-scale represented by PVGs, an analyst could assume that different PVGs were molded by different disturbance regimes).

[5] Potential vegetation types (PVTs) are often aggregated into higher-level groups for landscape-scale analysis. Generally, PVTs are aggregated into plant association groups (PAGs) or potential vegetation groups (PVGs). Analysts recently settled on PVG as an ideal aggregation unit because standards and guidelines in revised (draft) Forest Plans for Blue Mountains national forests (USDA Forest Service 2014) are stratified by PVG, and because PVGs are assumed to better reflect broad-scale disturbance regimes influencing species composition, forest structure, and stand density. Appendix 1 of this white paper provides a cross-walk table showing how PVTs are assigned to PAGs and PVGs for Blue Mountains section.

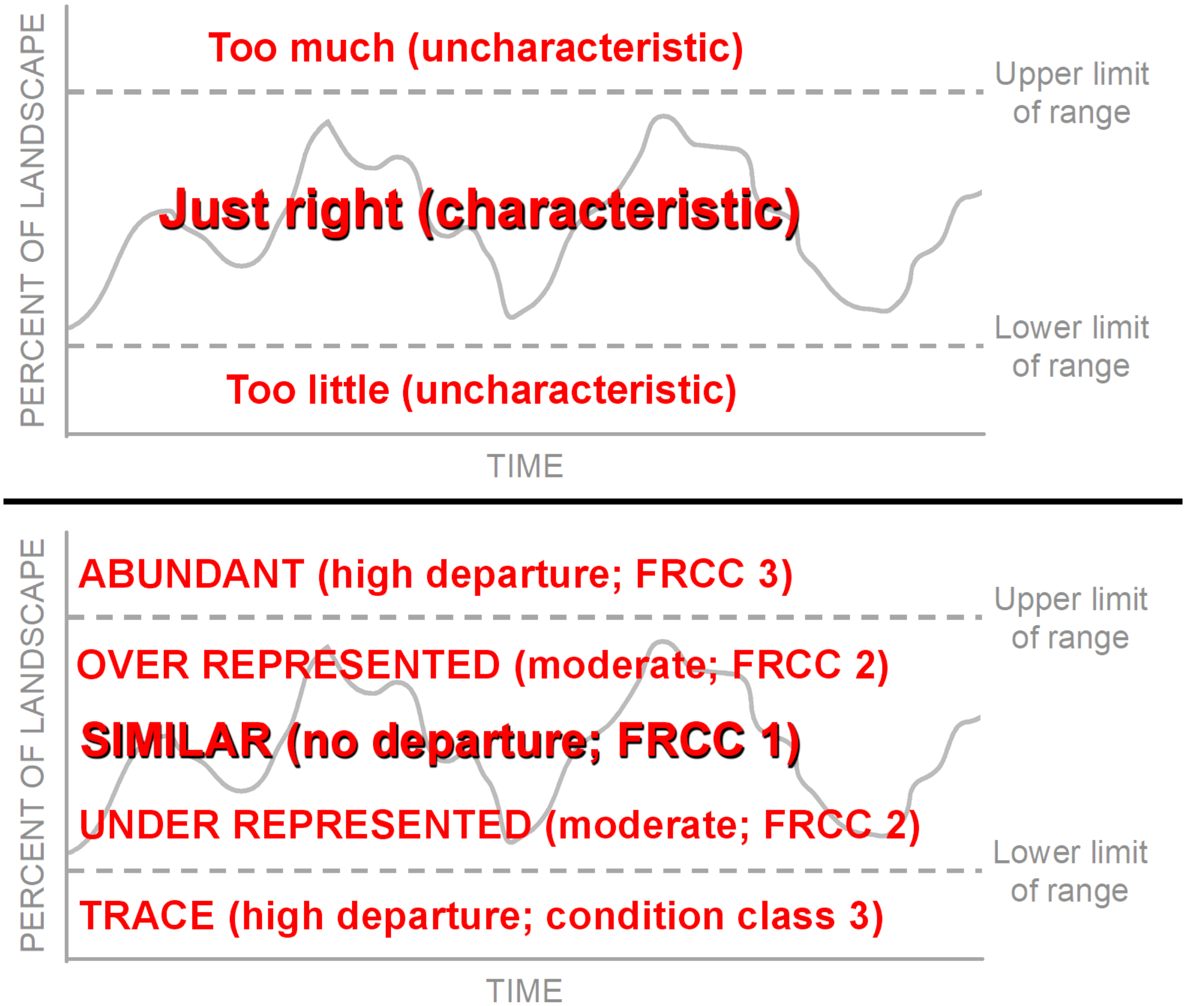


Figure 4 – Varying implementations of the range of variation (RV) concept, including RV use for an interagency Fire Regime Condition Class (FRCC) protocol (Barrett et al. 2010). Both examples use symbology contained in figure 1 as a foundation (the gray background material is adapted from fig. 1).

Top diagram is characterized as an 'Goldilocks' analogy because when existing amounts of an ecosystem component (composition, structure, density) occurs within its RV (e.g., below a range's upper limit, and above a range's lower limit), then it is interpreted as "just right" (characteristic). But when an ecosystem component occurs outside of its range, either by occurring above an upper limit or below a lower limit, then it is uncharacteristic (just like porridge that was too hot, or too cold, in the Goldilocks tale). Note that this implementation of the RV concept is somewhat simplistic – there are basically only two states or outcomes for an ecosystem component: within a range, or outside of a range.

Unlike a simplistic "yes or no" or "black or white" approach used in the top diagram, the bottom diagram is more nuanced and shows how RV was adopted for FRCC purposes. When an ecosystem component has little or no departure from historical (reference) conditions, it is characterized as 'Similar' and assigned an FRCC class value of 1. Existing conditions that are moderately departed from reference conditions are over- or under-represented and assigned an FRCC class value of 2.

Existing conditions that are highly departed from historical reference conditions are characterized as either 'Abundant' or 'Trace,' and assigned an FRCC class value of 3.

Proposed fuels treatments use FRCC outcomes as rationale (justification) for active management treatments to modify existing fire environments.

Planning Note: What if a planning area contains less than 1,000 acres of a PVG, but active vegetation treatments are proposed for it? This situation can be problematic because we assume that vegetation projects generally address RV results by proposing treatments that move over- or under-represented vegetation classes so they fall within their ranges of variation (see fig. 1) after treatment. (An exception to this generalization is WUI treatments, and other special circumstances, where RV analysis has little or no bearing on treatment design.) But for any biophysical environment not receiving an RV analysis (because it has less than 1,000 acres), we don't know which classes are over- or under-represented, and we also don't know if proposed treatments are expected to move classes closer to, or farther away from, their RV ranges.

This scenario often arises in a context of inclusions – most of a planning area consists of Dry Upland Forest PVG, for example, but small inclusions of Moist Upland Forest PVG occur in portions of it. Dry UF PVG has enough acreage to include in an RV analysis, but Moist UF PVG is scattered across the planning area and, in aggregate, it occupies less than 1,000 acres and cannot be included in an RV analysis. Under these circumstances, this question often arises: Would it be possible to propose Moist UF treatments for some inclusions located within, or adjacent to, proposed Dry UF treatment units?

One approach to this situation is to claim an Eastside Screens exemption (exempting a project from applying the ecosystem screen and its RV requirement) for "commercial thinning and understory removal sales located outside currently mapped old growth" (USDA Forest Service 1995). So, for this example, an exemption could be claimed for Moist UF PVG biophysical environment (BE), thereby obtaining relief from an Eastside Screens RV requirement (for a BE with less than 1,000 acres in a planning area). A conventional RV analysis, however, will still need to be completed for Dry UF PVG (no exemption is claimed for it) because it has more than 1,000 acres in the planning area. Note that an exemption is only appropriate for Moist UF PVG if proposed treatments are truly commercial thinnings or understory removals – an exemption could not be claimed, and is not appropriate, if regeneration cutting or non-thinning treatments are being proposed.

4. **Classify existing vegetation information into the same analysis categories included in tables 3, 5, 6, and 8**, all of which qualify as derived attributes because they are calculated (not measured) by using a combination of metrics from stand examination or photo interpretation surveys. White papers describe how the derived fields are calculated, as demonstrated by using three examples:
   (a) Forest species composition is characterized by using a derived field called vegetation cover type (table 2). Vegetation cover types are calculated by using a three-step process described in Powell (2013a: page 14).
   (b) Forest structure is characterized by using a derived field called forest structural stage (tables 3-4). Forest structural stages are calculated by using a process described in Powell (2013a: pages 12 and 35-36) as a first option, or in Powell (2012a: table 3 in that source) as a second option.

(c) Tree density is characterized by using a derived field called stand density class (table 5). Stand density classes are calculated from tabular information presented in Powell (2013b: pages 16-21 in that source provide calculation information by PVG).

Note: Vegetation characterization information is generally derived for a planning area by using Most Similar Neighbor (MSN) imputation software (Crookston et al. 2002, Moeur and Stage 1995). MSN uses canonical correlation analysis to derive a similarity function for a reference stand, and it then selects most similar non-reference stands by comparing detailed attributes (local variables) and lower-resolution indicator variables (global variables). Most-similar stands (for a reference stand) are selected by using a similarity function to maintain multivariate relationships between global and local variables.

Why do we care about this MSN methodology for vegetation project planning? One NEPA concern is data gaps – can a resource be adequately characterized for a full extent of a planning area? When using MSN correctly and appropriately, an answer to this question is a resounding 'yes' – every forested polygon ends up with detailed vegetation data, just as though a stand examination had been completed for every polygon. Contact a Forest vegetation analyst (incumbent is Donald Justice) for information about completing an MSN analysis for a project planning analysis area.

5. **Calculate existing amounts of each analysis category** (such as cover type, structural stage, tree density class) for an analysis area, as stratified by PVG, and convert the acreage for each category into its corresponding percentage value. A spreadsheet is helpful for this task (fig. 5).

   Calculation methodology is simple and straightforward – acreage for a particular category (such as stem exclusion or SE structural stage in fig. 5), by PVG, is divided by total acreage for the category – 3,200.9 acres of SE divided by 11,503.4 total acres of structural stage for the PVG = 27.8 or 28% (see fig. 5).

6. **Widespread utilization of geographic information system (GIS) technology** allows land managers to gain access to a wide variety of spatially-explicit information about ecological site conditions, mensurational stand metrics, land use allocations, and operability or implementation considerations. GIS allows grouping of forest stands into strata according to land allocations, site characteristics, ecological site potentials, and any number of other criteria (Horning et al. 2010).

   GIS technology is helpful for completing stratification as described in step #3 (PVG) and in this step #6, where stands with similar characteristics are being grouped into the same classes by using species composition, forest structure, or stand density.

Moist Upland Forest PVG:							
Struc Stage	**Acres**	**Combined Stage**	**Combined Acres**	**Current Percent**	**Lower RV Limit**	**Upper RV Limit**	**Interpretation**
BG	0.0	SI	397.5	3%	20%	30%	Well below RV
SI	397.5						
SEOC	1,913.0	SE	3,200.9	28%	20%	30%	Within RV
SECC	1,287.9						
UR	3,507.1	UR	3,816.3	33%	15%	25%	Above RV
YFMS	309.2						
OFMS	1,079.8	OFMS	1,079.8	9%	15%	20%	Below RV
OFSS	3,008.9	OFSS	3,008.9	26%	10%	20%	Above RV
Total	11,503.4		11,503.4				

Figure 5 – Example spreadsheet format for completing RV calculations. In this example, a database included eight structural stages from O'Hara et al. (1996) (Struc Stage column; BG = bareground, SI = stand initiation, SEOC = stem exclusion open canopy, SECC = stem exclusion closed canopy, UR = understory reinitiation, YFMS = young forest multi-strata, OFMS = old forest multi-strata, OFSS = old forest single stratum). Current Umatilla National Forest direction is to use five structural stages (Martin 2010), so some of the O'Hara et al. (1996) stages must be combined before completing an RV analysis. BG and SI stages are combined into an SI stage, SEOC and SECC stages are combined into an SE stage, and UR and YFMS stages are combined as a UR stage (see a Combined Stage column). Combined Acres, Current Percent, Lower RV Limit, and Upper RV Limit columns pertain to collapsed (combined) structural stages. Current percentage of each stage is compared to an historical range (Lower and Upper RV Limit columns) to derive an RV result (Interpretation column).

Using GIS and stratification techniques to generate categories or classes of vegetation condition (such as cover-type bins for forest types like ponderosa pine or Douglas-fir) can support landscape-scale planning because treatments are then proposed for classes or categories, rather than for individual polygons. This strategy adequately addresses site specificity requirements of NEPA because maps clearly depict distribution of classes or categories across a planning area (rather than individual polygons), and a project's proposed activities relate directly to classes or categories depicted on the map.

7. **Determine whether current conditions are within or outside of their range of variation** (see fig. 1) by comparing a calculated existing percentage with an RV percentage range for each analysis category.
   (a) RV analysis results are typically provided in a table where existing amounts (expressed in acres and as a percentage) are presented for each ecosystem component (cover type, structural stage, and density class), along with their corresponding RV ranges, and all tabular results are reported by PVG. Table 2 provides an example of a tabular presentation format.

Table 2: RV results for Moist Upland Forest PVG in a project planning area.

Structural Stage	Historical Range Percent	Historical Range Acres	Current Amount Percent	Current Amount Acres	HRV Interpretation	Screens Interpretation
Stand initiation	20-30	2300-3430	3	400	Below RV	
Stem exclusion	20-30	2300-3430	28	3200	Within RV	
Understory reinitiation	15-25	1715-2865	33	3820	Above RV	
Old forest SS	10-20	1150-2300	26	3010	Above RV	**Scenario A**
Old forest MS	15-20	1715-2300	9	1080	Below RV	

Note: Screens Interpretation column shows how HRV interpretation results (e.g., above/within/below RV) for Old Forest are used to identify whether forested lands within a biophysical environment need to comply with Scenario A or Scenario B from Wildlife Screen portion of Eastside Screens (Regional Forester's Forest Plan Amendment #2) (USDA Forest Service 1995).

(b) A tabular presentation format is not required, however, and some analysts prefer to portray results graphically by using shaded boxes to depict historical range values, and a large dot, star, or another symbol to denote an existing percentage. Figure 6 provides an example of a graphical presentation format – it includes the same data, in terms of historical ranges (gray vertical bars) and current percentages (square black markers), presented in table 2 above. [Increased detail provided by a tabular format is often used for NEPA; a visual format is often used for public meetings.]

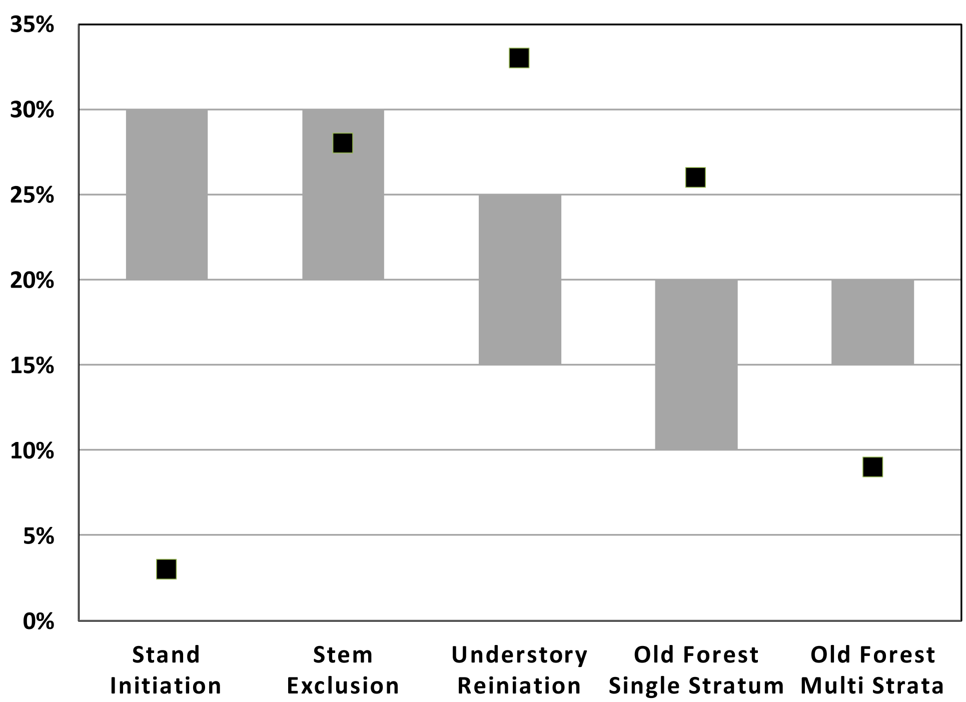


Figure 6 – RV results for a forest structural stage analysis, presented graphically in chart format in lieu of a tabular summary provided in fig. 5 and table 2 (e.g., the same data is used for figs. 5 and 6, and table 2). Gray bands are historical ranges; black markers show current percentages. This visual format for presenting RV results was implemented by using Excel.

8. **In a typical planning context, RV analysis described to this point is completed during what is termed a NFMA (National Forest Management Act) or Plan Consistency, plan-to-project, proposal development, or 'left side of the triangle' process (fig. 7) (all these terms pertain to the same portion of a Forest Service planning model shown in fig. 7)**.
   (a) A NFMA analysis is designed to examine existing conditions in a planning area, compare them with reference conditions (such as RV ranges) or desired future conditions, and then determine if differences between existing and reference or desired conditions warrant active management intervention. If magnitude of a difference between existing and reference conditions is substantial for a particular analysis indicator (such as the old forest structural stage), then the difference may qualify as a purpose and need to modify existing conditions in such a way as to move them closer to reference condition.
   My experience is that differences between existing and reference conditions provide compelling purposes and needs on which to base a vegetation management Purpose and Need statement. *For every project planning effort in which I participated as an interdisciplinary team silviculturist, purposes and needs for upland forest management treatment proposals were derived primarily from a comparison between historical and current RV percentages*.
   (b) If a NFMA analysis suggests that active management is warranted to address over- or under-representation of a particular ecosystem component (such as old forest), then NFMA results from this 'left side of the triangle' process provide a rationale for a Purpose and Need statement, which is then used to formulate a Proposed Action before initiating the NEPA process ('right side of the triangle'). You can think about it this way: NFMA analysis identifies a 'problem,' which is stated as a Purpose and Need, and a Proposed Action identifies the agency's preferred 'solution' to a problem.
   (c) RV results are often provided as issues or needs when formulating a Purpose and Need. In some instances, an issue or need is stated in general terms (a specific condition is over- or under-represented, for example). In other cases, an issue or need is stated in quite a bit of detail (at least X acres of condition Y needs to be transformed to condition Z in order to bring condition Z, and possibly condition Y as well, within their RV). Often, a unit's environmental coordinator will specify whether they prefer a general or detailed approach.
   Here are two issue or need statements stated in more general terms:
   Issue: Existing tree species composition is not within its range of variation.
   1. On dry-forest sites, ponderosa pine forest cover type is under-represented (below RV); Douglas-fir and grand fir cover types are over-represented (above RV).
   2. On moist-forest sites, Douglas-fir, western larch, broadleaved trees, and lodgepole pine forest cover types are under-represented; grand fir and spruce-fir cover types are over-represented.

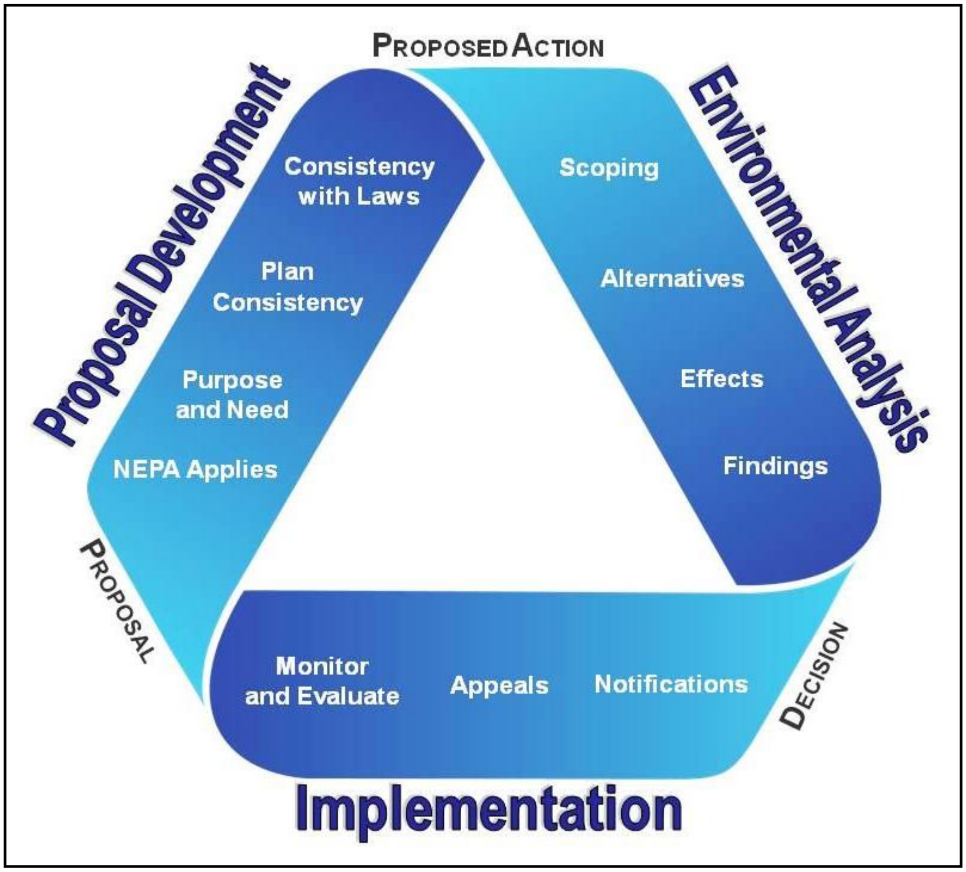


Figure 7 – Forest Service planning model (also known as NEPA triangle). RV analyses are used extensively during what is termed a NFMA or Forest Plan consistency evaluation, proposal development, or 'left side of the triangle' process. RV analyses are also utilized during environmental analysis (right side of the triangle).

(d) NFMA results are almost always addressed by using the NEPA process, regardless of which management activities (prescribed fire, timber harvest, etc.) are being considered as proposed actions in response to NFMA results; it is very unusual to be able to address NFMA results without using NEPA. [*Terminology note*: a timber sale is a management action or project; timber harvest (tree removal) is a management activity.]

9. Question: **Why use an RV analysis or another NFMA process to justify a vegetation management project? Why not use a Forest Plan instead?**
Answer: *A Land and Resource Management Plan does not compel action, it just authorizes it.*
This means that a compelling need for active vegetation management to modify existing vegetation conditions must come from a source other than a Forest Plan (and typically, it comes from project-scale planning). A Forest Plan will not tell you what to do (i.e., treat 4,300 acres of fuels in South Fork of Asotin Creek subwatershed), but after project-scale planning has been used to generate treatment proposals, a Forest Plan will tell you how the treatments should be designed (treatment methods and specifications must be consistent with applicable standards, guidelines, and other Forest Plan components).

10. Another Common Question: **Instead of conducting an RV analysis, why can't I use broad-scale Blue Mountains assessment findings as justification for proposing a vegetation management project?**

(a) Many scientifically rigorous reports provide broad-scale context for Blue Mountains vegetation management issues, including these items:

- Blue Mountains forest health report (Gast et al. 1991).
- "Restoring ecosystems in the Blue Mountains" (Caraher et al. 1992).
- "Forest health science perspectives" reports prepared for the Blue Mountains (Johnson 1994, Mutch et al. 1993, Tanaka et al. 1995, and Wickman 1992 are useful vegetation management sources).
- Reports produced for an Eastside forest ecosystem health assessment (Agee 1994, Everett 1994, Everett et al. 1994, Harvey et al. 1994, Hessburg et al. 1994, Huff et al. 1995, Jensen and Bourgeron 1994, Johnson et al. 1994, Lehmkuhl et al. 1994, Oliver et al. 1994, and Robbins and Wolf 1994 are useful vegetation management sources).
- Eastside forests scientific society panel report (Henjum et al. 1994).
- Eastside forest science panel review of eastern Oregon timber harvest practices (Johnson et al. 1995).
- Reports produced for an Interior Columbia Basin Ecosystem Management Project (Hessburg et al. 1999b,c,d; Quigley and Arbelbide 1997; and Quigley et al. 1996 are useful vegetation management sources).

(b) These broad-scale reports provide valuable context for a scale above your planning area. They can address questions like these: Is a situation indicating a purpose or need for action – existence of high amounts of overstocked forest on dry sites – common across the Blue Mountains, or is it specific to just your planning area? Reports can answer the first question (is a situation common across the whole Blues?), but an RV or NFMA analysis must be used to answer the second question (is a situation specific to just your planning area, or does it also occur in the Blues, but at a lesser or greater magnitude than for your planning area?). Although useful, broad-scale context cannot be used as sole justification for proposing vegetation management treatments because it is not site specific – broad-scale reports cited above pertain to whole Blue Mountains (or even larger areas), so they are too general to provide site-specific information for your specific planning area.

Broad-scale reports are valuable for explaining to the reader if your RV results are typical for a higher-level context in which a planning area occurs (is old forest deficient for the basin?), but ***they cannot substitute for actually completing an RV analysis for a specific planning area****.*

(c) There may be one exception to this situation, however. Ecosystem analysis at the watershed scale (EAWS) (REO 1995) is a mid-scale process; it has been completed for some portions of Umatilla National Forest, and it typically includes RV analyses for composition, structure, and density. Many RV analyses completed during EAWS were completed at a subwatershed scale (HUC6), and since it is common practice on Umatilla NF to combine several adjoining subwatersheds when establishing a planning area boundary, it may then be possible to extract RV analyses for appropriate subwatersheds from an EAWS report and use them to identify issues, concerns, and opportunities for project planning. And, vegetation databases compiled to support EAWS efforts used similar data fields and data resolution (specificity) as is used for project plans. [<u>Caution</u>: If using an EAWS is seriously being considered to provide project planning context, then its results need to be evaluated to ensure they are still reasonably current, as many EAWS reports are becoming dated. Have large wildfires or other disturbance events rendered the EAWS findings moot?] [<u>Tip</u>: If the EAWS alternative is pursued, then it may be wise to conduct a change detection analysis to validate that existing conditions have not changed substantially since an EAWS was completed. If questions or concerns are raised during scoping or at other points in a NEPA process, change detection analyses should reassure respondents that EAWS data adequately reflects current planning-area conditions.]

(d) Lacking an EAWS, an RV analysis must be used to characterize existing conditions of your planning area, and to put them in a meaningful context by comparing them against a baseline reference condition.

11. Use a database analysis to help determine where current conditions depart from RV. A database analysis helps prioritize potential treatment areas (which polygons have a high priority for active management?), and it can help answer the "why here, why now" NEPA imperative (e.g., it can help provide spatial and temporal context for potential vegetation treatment areas).

(a) Generally, database analysis during project planning involves a series of filters or sieves, ranging from most restrictive to least restrictive factors. The first sieve almost always involves Forest Plan management allocations because Plan direction (standards, guidelines) dictates the treatments that can, or cannot, be considered for implementation on lands assigned to a management area. Some Forest Plan management allocations allow timber management practices to occur (forested lands in these allocations are classed as 'suitable lands,' and they have what is referred to as 'scheduled harvest' in the Forest Plan), whereas other lands are classified as unsuitable and timber management is prohibited.

(b) *A timber sale cannot be used in unsuitable management areas to address a purpose and need for action (addressing an over- or under-representation of certain structural stages, for example) unless a project's NEPA documentation includes a site-specific Forest Plan amendment to make timber management permissible.*

<u>Note</u>: Forest Plan context varies by treatment activity. Many Forest Plan management allocations prohibiting timber management are suitable for prescribed fire. So even when vegetation management objectives cannot be addressed by using timber management activities, prescribed fire can almost always be considered *if it could accomplish them just as effectively.*

(c) After working through a Forest Plan sieve, other filters would then be applied. Some of them deal with operational considerations – can a polygon be accessed from existing transportation routes, or would new road developments be required? Does a polygon contain lands whose slope gradients allow implementation of a relatively low-cost yarding (logging) system, or would slope gradients or a lack of road access require a high-cost option such as skyline or helicopter yarding?

(d) After evaluating suitability, operational, and logistical filters, next steps typically involve resource-based considerations such as wildlife habitat connectivity or soil/water protections: Does a polygon occur in a wildlife connectivity corridor, or in an area where previous management activity has resulted in more than 15% detrimental soil disturbance?

12. **Consider how ecosystem components interact** (is the OFSS structural stage associated mostly with the ponderosa pine (PP) forest cover type?) and use these insights about interactions to identify opportunities to address needs related to more than one component with a single vegetation treatment. For a best-case scenario, could a single treatment address composition, structure, and density simultaneously?

(a) After removing from further consideration any polygons containing unsuitable lands or presenting other issues or concerns (step #11), a multi-factor process can then be used to identify which polygons could be treated to address several needs simultaneously.

An example: Let's assume that an RV analysis found Dry Upland Forest in a planning area to have an over-representation of OFMS structural stage, Douglas-fir cover type, and high stand density, and an under-representation of OFSS structural stage, ponderosa pine cover type, and low stand density. Now, let's further assume that a planning area's vegetation database has 95 polygons with a cover type code of mix-PSME (mix-Douglas-fir), a structural stage code of OFMS (old forest multi-strata), and a density class code of H (High). Further inspection of this data suggests that many polygons with a mix-PSME cover type contain some amount of ponderosa pine stocking, even though it is not a plurality tree species (if it had been, then cover type would have been coded as mix-PIPO). At this point, you realize it might be possible to prescribe one cutting method for these 95 polygons (such as improvement cutting or free (proportional) thinning) and have their post-treatment composition, structure, and density all address the RV results – after implementing a treatment, you believe they would classify as PIPO or mix-PIPO (ponderosa pine) cover type, OFSS (old forest single stratum) structural stage, and Low stand density class. Thus, prescribing one treatment method for a set of 95 polygons would reduce over-represented components (mix-PSME, OFMS, and H density) and simultaneously increase under-represented components (ponderosa pine, OFSS, and L density).

[*Ahh…silvicultural nirvana has now been reached*!]

<u>Bottom Line</u>: These multi-criteria polygons should be your first priority for

additional analysis because treating them would address all three upland-forest components concurrently: species composition, forest structure, and stand density.

(b) Example (a) describes how polygons can be evaluated across components, i.e., which treatment polygons might simultaneously meet objectives relating to composition, structure, and density? It is also necessary to evaluate polygons within a component – how could various suites of polygons contribute to structure goals for a watershed? Let's say that dry-forest UR is over-represented within a watershed, and old-forest stages (particularly OFSS) are under-represented. Further analysis of polygon characteristics suggests that some UR polygons have a high quadratic mean diameter (QMD), 18-inches or more in this instance, and treating them with a 'low' silvicultural treatment (such as low thinning), which would preferentially remove small-diameter trees, will increase the QMD enough to move these polygons across a threshold diameter (21 inches) for old forest. Implementing such treatments would allow UR polygons to immediately 'become' OFSS or OFMS polygons, a transition addressing two situations simultaneously: over-representation of UR, and under-representation of OF.

But, what happens if treating UR polygons to move acreage of this stage down to a point falling within its range causes an increase of stem exclusion (SE), which is within its range before treatment? And, what happens if enough UR is treated to cause the SE stage to exceed its range on the upper end? Answers to these questions depend on project-level structure objectives, and how they will be 'handled' during NEPA. Will SE being created from UR treatments have a high QMD and be expected to 'grow' into OFSS within a few decades? Often, the answer to this question is 'yes,' in which case prescribed fire could be used in the short-term to limit establishment of new regeneration, which could cause newly-created SE to transition back to UR (undesirable outcome). If prescribed fire successfully inhibits new regeneration and prevents a return to UR, increased tree growth associated with low thinning will allow post-treatment SE stands to transition quickly to OFSS (desirable outcome).

(c) Not every high-priority polygon will necessarily be included in a project's proposed action alternative because some of them might be 'discarded' for other reasons – they are too far from a road to be economically viable, they are on steep slopes and logging systems are too costly for a small amount of volume removed, and so forth. But as described in step #11, you generally would have already applied operational and logistical filters by this point in a planning process, in which case you can be confident (within the accuracy of your polygon data) that high-priority polygons are truly available for active management. It would be more common to drop polygons from further consideration due to interdisciplinary concerns – they may be located in a wildlife connectivity corridor, they may be providing crucial elk hiding or security cover, etc.

13. **From a temporal standpoint, consider an area's recent disturbance history** and then decide if an RV analysis is appropriate now. For example, an RV analysis was not completed when conducting an ecosystem analysis at the watershed scale (REO 1995) for the Tower Fire (Powell 1997), primarily because much of the 52,000-acre assessment area had just experienced uncharacteristic fire effects (more stand-replacing severity than is typical for fire regime 1), postfire composition, structure, and density did not reflect a dynamic equilibrium created by properly functioning disturbance regimes, and the assessment area had been delineated to only include the fire extent (no area outside the wildfire footprint had been included).

USING RV TO EVALUATE SPECIES COMPOSITION

Plant species occur in either pure or mixed communities called cover types. Tree species occurrence in a project planning or analysis area can be characterized by using cover types, a classification of existing vegetation composition (Eyre 1980, Shiflet 1994). Cover type codes reflect majority or plurality tree species abundance, and they apply to both pure and mixed stands.

RV information for species composition is expressed for vegetation cover types, and it is derived primarily from Vegetation Dynamics Development Tool modeling completed for Blue Mountains ecosystems (fig. 8). Range of variation information for vegetation cover types is stratified by upland-forest potential vegetation group and provided in table 3.

Table 3 expresses percentages of a landscape (preferably at least 15,000-35,000 acres in size) occupied by various vegetation cover types (ponderosa pine, grand fir, etc.). A cover type may have a majority of one species (e.g., grand fir comprises more than 50% of stocking, coded as ABGR); if less than 50% of a species is predominant, then a cover type is named for the species comprising a plurality of stocking (grand fir comprises less than 50% of stocking, coded as mix-ABGR).

<u>Note</u>: It is important to emphasize that cover type information shown in table 3 does NOT pertain to the species composition of an individual polygon. In other words, species composition of a typical moist-forest stand would not be expected to consist of 5-15% ponderosa pine, 15-30% Douglas-fir, and so forth – species ranges presented in table 3 refer to percentages of a moist-forest **landscape** supporting ponderosa pine cover types, Douglas-fir cover types, and so forth (in other words, a moist-forest landscape would be expected to contain 5-15% ponderosa pine cover type (e.g., stands of ponderosa pine), 15-30% Douglas-fir cover type, and so forth).

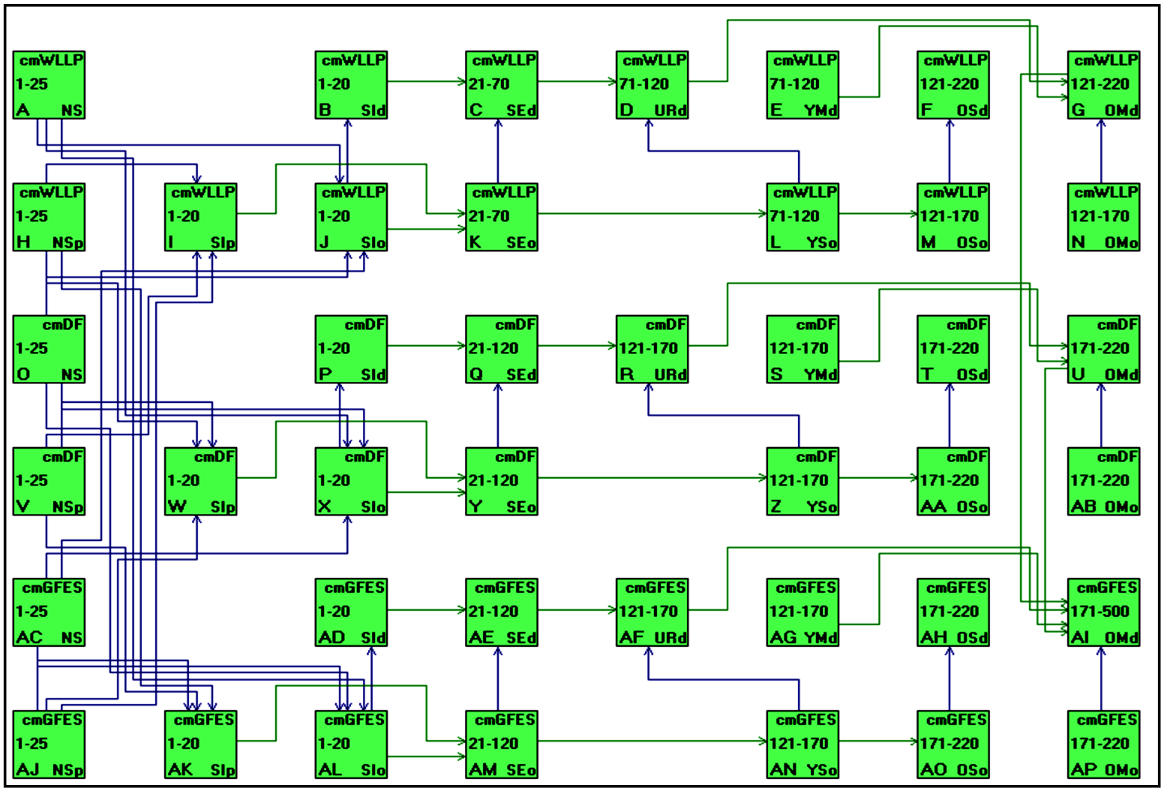


Figure 8 – Schematic (akin to a wireframe diagram or circuit board) from a VDDT model showing vegetation cover-type states (green boxes) and transitions (colored arrows) for the cool moist (cm) upland forest plant association group. Similar vegetation cover type diagrams (models) exist for other plant association groups, and for various combinations of forest structural stages and stand density classes. VDDT modeling was used to generate RV information for most vegetation standards and guidelines contained in revised Forest Plans for Blue Mountains national forests (Forest Plan revisions are in draft form; USDA Forest Service 2014).

VDDT is in a class of models designed to examine vegetative change for landscape-scale planning (Barrett 2001). It has been used to estimate vegetation conditions in support of Forest Plan revision (Merzenich and Frid 2005), to examine interactions between vegetation conditions and wildlife habitat (Shifley et al. 2008), to predict changes for ecosystems of special concern such as quaking aspen (Strand et al. 2009), and to support broad-scale fire regime analyses (Swetnam and Brown 2010).

Table 3: Range of variation information for species composition (vegetation cover types), expressed as percentages by potential vegetation group.

	POTENTIAL VEGETATION GROUP (PVG)		
Vegetation Cover Type[1]	**Dry UF**	**Moist UF**	**Cold UF[2]**
	Range of Variation (Percentage)		
Grass-forb	0-5	0-5	0-5
Shrub	0-5	0-5	0-15
Western juniper	0-5	0	0
Ponderosa pine	50-80	5-15	0-5
Douglas-fir	5-20	15-30	5-15
Western larch	1-10	10-30	5-15
Broadleaved trees	0-5	1-10	0-5
Lodgepole pine	0	25-45	25-45
Western white pine	0-5	0-5	0

Vegetation Cover Type[1]	POTENTIAL VEGETATION GROUP (PVG) Dry UF	Moist UF	Cold UF[2]
Grand fir	1-10	15-30	5-15
Whitebark pine	0	0	0-10
Subalpine fir-Engelmann spruce	0	1-10	15-35

Sources/Notes: Derived from state-and-transition modeling by using Vegetation Dynamics Development Tool (VDDT). Potential vegetation group is described in Powell et al. (2007); UF = Upland Forest.

[1] Cover types reflect existing vegetation composition of a polygon (Eyre 1980, Shiflet 1994). Cover type codes are described in Powell (2013a); cover types consist of these coding combinations:

Grass-forb: all grass and forb codes
Shrub: all shrub codes
Western juniper: JUOC and mix-JUOC
Ponderosa pine: PIPO and mix-PIPO
Douglas-fir: PSME and mix-PSME
Western larch: LAOC and mix-LAOC
Lodgepole pine: PICO and mix-PICO
Western white pine: PIMO and mix-PIMO
Grand fir: ABGR and mix-ABGR
Whitebark pine: PIAL and mix-PIAL
Broadleaved trees: POTR, POTR2, mix-POTR, and mix-POTR2
Subalpine fir-Engelmann spruce: ABLA, PIEN, mix-ABLA, and mix-PIEN

[2] When a vegetation cover type has a zero in a PVG column (not zero as a lower limit of a range – just zero by itself), it means that a cover type is not believed to have existed historically in that biophysical environment.

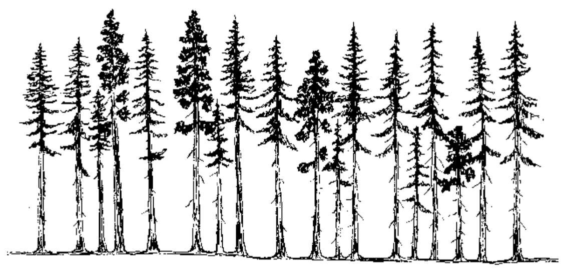
USING RV TO EVALUATE FOREST STRUCTURE

Oliver and Larson (1996) developed a forest structure classification system involving four structural stages (table 4). Oliver and Larson's (1996) classification system works well for conifer forests located west of the Cascade Mountains, but it was not found to adequately represent a full spectrum of structural conditions for interior Pacific Northwest, where forest structure tends to be more varied. Therefore, an Oliver and Larson (1996) system was expanded to seven classes to encompass more structural variation (O'Hara et al. 1996).

Between 1993 and 1995, when Pacific Northwest Region of USDA Forest Service issued two versions of a Regional Forester's Forest Plan Amendment referred to as Eastside Screens (USDA Forest Service 1994, USDA Forest Service 1995), it established a procedural requirement to use RV as an analytical technique by comparing current percentages of forest structural stage with their historical ranges.

When fire suppression allowed interior Douglas-fir and grand fir to invade dry-forest sites by preventing surface fire from fulfilling its role as a tree-thinning process, vertical forest structure was transformed when leaf area (foliage biomass) shifted downward from one high canopy layer (such as old forest single stratum structural stage) to multiple lower layers (such as understory reinitiation stage) (Agee 1996; Arno et al. 1995; Brown et al. 2003; Graham et al. 1999, 2004).

Table 4: Description of forest structural stages.

	**Stand Initiation (SI)**. Following a stand-replacing disturbance such as wildfire or tree harvest, growing space is occupied rapidly by vegetation that survives, or colonizes the area afterward. Survivors survive above ground, or they initiate new growth from underground organs or from seed stored on site. Colonizers disperse seed into disturbed areas, it germinates, and then new plants establish and develop. A single canopy stratum of tree seedlings and saplings is dominant in this stage.
	**Stem Exclusion (SE)**. In this single-cohort stand structure, trees initially grow fast and quickly occupy their growing space, competing strongly for sunlight and moisture. Because trees are tall and reduce subcanopy light levels, understory plants (including smaller trees) are shaded and grow slowly. Species needing sunlight often die; shrubs and herbs may go dormant. In this stage, establishment of new trees is precluded by a lack of sunlight (stem exclusion closed canopy) or soil moisture (stem exclusion open canopy).
	**Understory Reinitiation (UR)**. As a forest develops, a new tree cohort eventually gets established as overstory trees begin to die, or because they no longer fully occupy growing space. A period of overstory crown shyness occurs when tall trees abrade each other in the wind (Putz et al. 1984). Regrowth of understory seedlings and other vegetation then occurs; trees begin stratifying into vertical layers. UR consists of overstory trees at low to moderate density, with small trees underneath.
	**Old Forest (OF)**. Many age classes and vegetation layers mark this structural stage containing large, old trees. Snags and decayed fallen trees may also be present, leaving a discontinuous overstory canopy. The drawing shows a single-layer ponderosa pine stand reflecting the influence of frequent surface fire on dry-forest sites (old forest single stratum; OFSS). Surface fire is not common on cold or moist sites, so these environments generally have multi-layer stands with large trees in an uppermost stratum (old forest multi strata; OFMS).

Sources/Notes: Based on O'Hara et al. (1996), Oliver and Larson (1996), and Spies (1997). Note that O'Hara et al. (1996) also included a young multi-strata stage, which is not included here (although it could be viewed as a variant of understory reinitiation). Eastside Screens (USDA Forest Service 1995) refers to old-forest stages as 'multi-stratum, with large trees,' and 'single stratum, with large trees.'

Transformation of vertical forest structure is an important issue because it creates understory layers functioning as ladder fuel, increasing the probability that surface fire can transition to crown fire (Fiedler et al. 2004, Graham et al. 2004, Mason et al. 2003, Peterson et al. 2005, Stephens 1998). For this reason, forest structure is typically included in a fuels analysis to assess ladder-fuel trends.

RV estimates for forest structural stages, as derived from state-and-transition modeling by using the Vegetation Dynamics Development Tool (VDDT), were compared with other RV sources to determine if VDDT values are consistent with what has been traditionally reported for the Blue Mountains during the last 20 years.

When Blue Mountain VDDT results for structural stages were compared with other sources providing structural stage information, these sources were used for the comparison:

- Caraher Report (Caraher et al. 1992).
- Eastside Forest Ecosystem Health Assessment (Lehmkuhl et al. 1994).
- Eastside Forests Scientific Society Panel (Henjum et al. 1994).
- Ecosystem components assessment for the Interior Columbia Basin Ecosystem Management Project (ICBEMP) (Quigley and Arbelbide 1997).
- Landscape-level comparison of historical and current conditions for ICBEMP area (Hessburg et al. 1999b).
- Terrestrial vertebrate source habitats for ICBEMP area (Wisdom et al. 2000).
- Historical RV estimates for central Idaho (Morgan and Parsons 2001).
- Analysis of pre-management era patterns of forest structure for mixed-conifer forests (Hessburg et al. 2007).
- Simulation modeling for upper Grande Ronde River sub-basin (INLAS project) (Hemstrom et al. 2007).
- Fire and fuel model scenario planning for northeast Oregon (Wales et al. 2007).

A structural-stage comparison exercise focused on abundance of old-forest (late-old) structure by potential vegetation group. Other sources (see list above) found that estimated RV for historical levels of old forest on dry upland sites in Blue Mountains varied from 10 to 80%; VDDT estimates of 45-75% are within this range.

Other sources found that estimated RV for historical levels of old forest on moist upland sites in the Blue Mountains varied from <10 to 60%; VDDT estimates of 25-40% are within this range (Countryman and Justice 2010).

As an example of a comparison process, Hemstrom et al. (2007) used VDDT to simulate landscape composition for dry upland forests under a natural fire regime. They found that mean percentage of forested land in an old forest single stratum structural stage was just under 20%, whereas mean percentage in an old forest multi-strata structural stage was less than 5%.

When Wimberly and Kennedy (2008) completed a similar modeling exercise for warm dry forests of Blue Mountains, they found that about 15% was in an old forest single stratum structural stage, and 4% was in an old forest multi-strata structural stage.

RV information for forest structure is expressed for forest structural stages, and it is derived from VDDT (Vegetation Dynamics Development Tool) state-and-transition modeling completed specifically for Blue Mountain ecosystems (fig. 8 illustrates some concepts of the VDDT modeling). Range of variation information for forest structural stages, as stratified by potential vegetation group, is provided in table 5.

Table 5: Range of variation information for forest structural stages, expressed as percentages by potential vegetation group.

Potential Vegetation Group	FOREST STRUCTURAL STAGE SI	SE	UR	OFSS	OFMS
	Range of Variation (Percentage)				
Cold Upland Forest	20-45	15-30	10-25	5-20	10-25
Moist Upland Forest	20-30	20-30	15-25	10-20	15-20
Dry Upland Forest	15-30	10-20	0-5	40-65	1-15

Source/Notes: Derived from state-and-transition modeling by using Vegetation Dynamics Development Tool (VDDT). These ranges are identical to those contained in a draft Environmental Impact Statement (2014) for revised Land and Resource Management Plans (Forest Plans) for Blue Mountains national forests (USDA Forest Service 2014). Potential vegetation group is described in Powell et al. (2007). Forest structural stages are described in table 4.

USING RV TO EVALUATE STAND DENSITY

Stand density is a characterization of tree stocking for an area. It expresses number of tree stems occupying a unit of land. Stocking can be expressed as a 'stand density index' or as some other measure of relative density, or it can be quantified in absolute terms as a number of trees or amount of basal area, wood volume, or canopy cover for an area (Powell 1999).

Published stocking guidelines are available for evaluating stand density levels (Cochran et al. 1994; Powell 1999, 2013b). By using stocking guidelines in conjunction with potential vegetation groups, it is possible to estimate how much forestland acreage is currently overstocked, and how it compares to a range of variation for this ecosystem component.

RV information for stand density is expressed for stand density classes, and it is derived from VDDT (Vegetation Dynamics Development Tool) state-and-transition modeling completed specifically for Blue Mountain ecosystems (see fig. 8 for an example of VDDT modeling). Range of variation information for stand density classes, as stratified by potential vegetation group, is provided in table 6.

White paper F14-SO-WP-Silv-36, "Tree Density Protocol for Mid-Scale Assessments," provides additional detail and context for mid-scale stand density information; White Paper 36 provides stand-density information expressed by plant association group and potential vegetation group (Powell 2013b).

Table 6: Range of variation information for stand density classes, expressed as percentages by potential vegetation group.

Stand Density Class (expressed as basal area, in ft²/acre at 10″ QMD)	Potential Vegetation Group		
	Dry UF	Moist UF	Cold UF
	Range of Variation (Percentage)		
Low (dry: <55; moist: <100; cold: <80)	40-85	20-40	15-35
Moderate (dry: 55-85; moist: 100-150; cold: 80-120)	15-30	25-60	20-40
High (dry: >85; moist: >150; cold: >120)	5-15	15-30	25-60

Source/Notes: Derived from Powell (2013b). Potential vegetation group is described in Powell et al. (2007). QMD is quadratic mean diameter. Basal area values in this table are derived from weighted-average stand density index stocking levels pertaining to mixed-species, even-aged stands – Dry UF assumes a species mix of 70% ponderosa pine, 20% Douglas-fir, and 10% grand fir; Moist UF assumes a species mix of 30% Douglas-fir, 20% western larch, 20% lodgepole pine, and 30% grand fir; Cold UF assumes a species mix of 10% Douglas-fir, 10% western larch, 50% lodgepole pine, 20% Engelmann spruce, and 10% subalpine fir. Powell (2013b) provides additional stand-density-class metrics in the form of stand density index, trees per acre, and canopy cover.

USING RV TO EVALUATE CANOPY FUEL LOADING

When considering fire effects on vegetation and other ecosystem components, crown fire is acknowledged to be the most severe of three fire types – ground fire, surface fire, and crown fire (Pyne et al. 1996). Although some amount of crown fire is normal and expected for fire regime groups III, IV, and V (Schmidt et al. 2002), a large amount of crown fire is neither normal nor expected for the dry forests of fire regime group I (Agee 1993).

Because dry forests are being affected by crown fire with increasing regularity (Mutch et al. 1993), and as treatments are being planned for wildland-urban interface where crown fire can seldom be tolerated regardless of fire regime, fire managers need tools to help them evaluate crown fire susceptibility for all forested lands.

To help evaluate crown-fire susceptibility, RV information was developed for three classes of canopy fuel loading (canopy biomass). This canopy-biomass information is provided in table 7.

Canopy fuel loading (table 7) is stratified by potential vegetation group because PVG is broadly correlated with fire regime – Dry Upland Forest PVG correlates with Fire Regime I; Moist Upland Forest correlates with Fire Regime III; Cold Upland Forest correlates with Fire Regime IV.

White paper F14-SO-WP-Silv-37, ‘Tree Density Thresholds as Related to Crown-Fire Susceptibility’ (Powell 2017), along with a journal article, *Estimating crown fire susceptibility for project planning* (Powell 2010), provide additional detail about how to use stand density information to characterize and evaluate crown-fire susceptibility for forested ecosystems of the Blue Mountains.

Table 7: Range of variation information for canopy biomass classes, expressed as percentages by potential vegetation group.

Potential Vegetation Group	Fire Regime Group[2]	CANOPY BIOMASS CLASS[1] Low (≤.05 kg/m³ CBD)	Moderate (.06-.09 kg/m³ CBD)	High (≥.10 kg/m³ CBD)
		Range of Variation (Percentage)		
Dry Upland Forest	I	60-90	20-60	10-20
Moist Upland Forest	III	20-50	50-70	20-50
Cold Upland Forest	IV	10-20	20-60	60-90

Source/Notes: Based on Agee (1998). Potential vegetation group is described in Powell et al. (2007).

[1] Canopy biomass class is a derived database field; it can be calculated by using queries contained in Powell (2010). CBD is crown bulk density, expressed as kilograms per cubic meter of crown volume. Class breakpoints are as follows: .05 kg/m³ = CBD threshold below which crown fire is unlikely; .10 kg/m³ = CBD threshold above which crown fire is easily sustained (Powell 2010).

[2] Fire regime group describes a fire environment by characterizing fire frequency, fire intensity, fire severity, fire extent, fire timing, and historical burned area (Schmidt et al. 2002). For forest environments in the Blue Mountains, three fire regime groups are most important: Fire regime group I: surface; Fire regime group III: mixed; Fire regime group IV: replacement.

USING RV TO EVALUATE INSECT AND DISEASE SUSCEPTIBILITY

RV is not intended to characterize a static, unchanging environment. It reflects effects of ecological processes with important implications on ecosystem behavior, such as an ecosystem's capacity to function properly in a constantly changing environment.

Ecosystems of interior Pacific Northwest evolved with a steady diet of fires, insect outbreaks, disease epidemics, floods, landslides, human uses, and weather cycles. Change was, and still is, a constant in their existence. RV is designed to characterize a range of vegetation composition, structure, and density resulting from wildfires and other agents of change (Morgan et al. 1994).

Resilient forests not only tolerate periodic disturbance, they may depend on it for rejuvenation and renewal (Johnson et al. 1994). Significant changes in magnitude (extent), intensity, or pattern of disturbance, however, may be indicative of impaired ecological integrity and resilience (Sampson and Adams 1994).

Perhaps an effective framework for evaluating forest health is range of variation – are effects of changes caused by insects, diseases, and wildfire consistent with what would be expected (the RV) for similar ecosystems and vegetation conditions? Recent forest health assessments, for example, suggest it might be appropriate to characterize dry forest ecosystems of the Blue Mountains as out-of-balance (Christensen et al. 2007, Powell 2014, Rainville et al. 2008).

When dry forests are evaluated by using RV, recent high levels of insect and disease activity are not totally unexpected, but they function as a symptom of an underlying problem – composition, structure, and density of these ecosystems are currently outside their RV (Caraher et al. 1992, Gast et al. 1991, Hessburg et al. 1994, Mutch et al. 1993, Oliver et al. 1994, Sampson and Adams 1994, Shlisky 1994, Wickman 1992).

Since composition, structure, and density change as forest development progresses, it is important that land managers understand how forest succession influences insect, disease, and crown-fire susceptibility to ensure that management activities are placed on a sound ecological foundation: "manipulation of a forest ecosystem should work within the limits established by natural disturbance patterns prior to extensive human alteration of the landscape" (Hunter 1999, page 29).

Susceptibility is defined as a set of conditions that make a forest stand vulnerable to substantial injury from insects or diseases. Susceptibility assessments do not predict when insects or diseases might reach damaging levels; rather, they indicate whether stand conditions are conducive to declining forest health, as reflected by increasing levels of tree mortality from insect and disease organisms.

Drought, ecological site potential (potential vegetation type), species composition and abundance, tree size, forest structure (canopy layering, structural stage), stocking (stand density), intra-stand variability (clumpiness), and other biophysical factors influence susceptibility and vulnerability to insect and disease disturbances (Hessburg et al. 1999, Lehmkuhl et al. 1994, Schmitt and Powell 2005).

Trees with increased insect or disease susceptibility often occur in dense forests where they face greater competition for soil moisture, nutrients, and other resources. Ponderosa pines in high-density stands, for example, have lower xylem water potentials and rates of photosynthesis, indicating greater drought stress (i.e., high tree density causes physiological drought, in contrast to climatic drought resulting from reduced precipitation). These stressed trees have decreased resin production and foliar toughness, suggesting an increased susceptibility to insect and pathogen attack (Kolb et al. 1998).

Once lodgepole pine, ponderosa pine, and other coniferous species respond physiologically to thinning (typically by 3 to 5 years after thinning, when crowns and roots have expanded into growing space liberated by the thinning), their improved vigor promotes increased production of defensive chemicals and resins enhancing beetle resistance (Bradley 1963, Christiansen et al. 1987; Feeney et al. 1998; Franceschi et al. 2005; Kolb et al. 1998, 2007; McDowell et al. 2007; Mitchell and Martin 1980; Perrakis and Agee 2006; Shrimpton 1978; Wallin et al. 2008).

To provide a process for evaluating insect and disease susceptibility, range of variation information was developed for nine insect and disease agents, and three classes of susceptibility (high, moderate, low); it is stratified by potential vegetation group and provided in table 8.

Table 8: Range of variation information for insect and disease susceptibility, expressed as percentages by agent and potential vegetation group.

Insect and Disease Agents[1]	POTENTIAL VEGETATION GROUP (PVG) Dry UF	Moist UF	Cold UF
	Range of Variation (Percentage)		
Defoliating insects			
Low susceptibility	40-85	5-20	40-95
Moderate susceptibility	15-30	20-30	15-25
High susceptibility	5-15	35-80	5-10
Douglas-fir beetle			
Low susceptibility	35-75	30-60	45-95
Moderate susceptibility	15-30	20-40	10-25
High susceptibility	10-25	10-30	5-10
Fir engraver			
Low susceptibility	45-95	30-70	35-75
Moderate susceptibility	10-25	10-20	20-45
High susceptibility	5-10	20-40	5-10
Spruce beetle			
Low susceptibility	0-0	50-95	10-30
Moderate susceptibility	0-0	10-25	30-50
High susceptibility	0-0	0-10	20-50
Bark beetles in ponderosa pine			
Low susceptibility	35-75	30-65	55-95
Moderate susceptibility	15-35	15-30	5-30
High susceptibility	10-20	15-35	0-5
Mountain pine beetle in lodgepole pine			
Low susceptibility	55-90	30-60	30-50
Moderate susceptibility	5-35	25-40	15-40
High susceptibility	0-5	5-30	15-40
Douglas-fir dwarf mistletoe			
Low susceptibility	30-60	30-65	40-90
Moderate susceptibility	10-35	20-45	20-30
High susceptibility	20-35	10-20	0-10
Western larch dwarf mistletoe			
Low susceptibility	55-95	5-20	10-20
Moderate susceptibility	5-30	15-40	20-50
High susceptibility	0-5	40-70	30-60
Root diseases			
Low susceptibility	35-75	5-25	30-65
Moderate susceptibility	20-35	20-40	20-45
High susceptibility	5-20	35-65	10-15

Sources/Notes: Derived from Schmitt and Powell (2012). Queries for calculating susceptibility ratings are available from Schmitt and Powell (2005). PVG is described in Powell et al. (2007).

[1] Defoliating insects includes western spruce budworm and Douglas-fir tussock moth; bark beetles in ponderosa pine includes western and mountain pine beetles; root diseases include laminated root rot and Armillaria root disease.

GLOSSARY

Biophysical environment. Landscape-level unit of composition and structure, with its associated environmental gradients and processes of change (Quigley and Arbelbide 1997).

Cover type. Plant species forming a plurality of composition across a given land area, e.g., the Engelmann spruce-subalpine fir, ponderosa pine-Douglas-fir, or lodgepole pine forest cover types (Helms 1998). Forest cover types of United States and Canada are described in Eyre (1980). Rangeland cover types of United States are described in Shiflet (1994).

Disturbance. A relatively discrete event that disrupts the structure of an ecosystem, community or population, and changes resource availability or the physical environment. Disturbances include processes such as fires, floods, insect outbreaks, disease epidemics, and windstorms (Dodson et al. 1998).

Disturbance regime. Spatial and temporal dynamics of disturbance events over a long time period. Characterizing a disturbance regime includes attributes such as spatial distribution of disturbance events; disturbance frequency (number of disturbance events in a specified time interval, or probability of a disturbance event occurring within a particular time interval); return interval (average time between successive disturbance events); rotation period (length of time until an area equivalent to the size of an analysis area would be affected in one disturbance event); disturbance size; and the magnitude, or intensity, of a disturbance event (Dodson et al. 1998).

Ecosystem. A spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and elements of an abiotic environment within its boundaries. An ecosystem is commonly described in terms of its:
(1) <u>Composition</u>. Biological elements within different levels of biological organization, from genes and species to communities and ecosystems.
(2) <u>Structure</u>. Organization and physical arrangement of biological elements, such as snags and down woody debris, vertical and horizontal distribution of vegetation, stream habitat complexity, landscape pattern, and connectivity.
(3) <u>Function</u>. Ecological processes that sustain composition and structure, such as energy flow, nutrient cycling and retention, soil development and retention, predation and herbivory, and natural disturbances such as wind, fire, and floods.
(4) <u>Connectivity</u>. Connectivity provides important connections between patches or non-adjacent habitats within a larger landscape (USDA Forest Service 2012a).

Hierarchy. "A general integrated system comprising two or more levels, with higher levels controlling to some extent the characteristics of lower levels. This means that ecosystems can be viewed spatially and temporally as occurring within organizational levels" (Haynes et al. 1996).

Landscape. A defined area irrespective of ownership or other artificial boundaries, such as a spatial mosaic of terrestrial and aquatic ecosystems, landforms, and plant communities, repeated in similar form throughout such a defined area (USDA Forest Service 2012a).

Plant association. A plant community with similar physiognomy (form and structure) and floristics; commonly it is a climax community (Allaby 1998). It is believed that:
(1) individual species in an association are, to some extent, adapted to each other;
(2) an association is made up of species with similar environmental requirements; and
(3) an association has some degree of integration (Kimmins 1997).

Plant association group (PAG). Groupings of plant associations, and other taxonomic units classified as potential vegetation types (PVTs), such as plant community types and plant communities, that represent similar ecological environments as characterized by using temperature and moisture regimes.

For the Blue Mountains section in the national hierarchy of terrestrial ecological units, the PVT composition for each plant association group is described in Powell et al. 2007.

Potential vegetation (PV). "Potential vegetation (PV) is vegetation that would likely develop on a given site if all successional sequences were completed, without human interference, under present site conditions. Potential vegetation types are the plant species that might grow on a given site in the absence of disturbance" (USDA Forest Service 1996).

Potential vegetation group (PVG). An aggregation of plant association groups (PAGs) with similar environmental regimes (temperature or moisture relationships) and dominated by similar types of plants.

For the Blue Mountains section in the national hierarchy of terrestrial ecological units, the PAG composition for each potential vegetation group is described in Powell et al. 2007.

Potential vegetation type (PVT). "A potential vegetation type (PVT) is any taxonomic unit described in a Blue Mountains PV classification report, except for series (e.g., Crowe and Clausnitzer 1997, Johnson 2004, Johnson and Clausnitzer 1992, Johnson and Simon 1987, Johnson and Swanson 2005, Swanson et al. 2010, Wells 2006); PVT includes plant associations, plant community types and plant communities."

For Blue Mountains section in a national hierarchy of terrestrial ecological units, PVT composition is summarized in Powell et al. 2007.

Appendix 1 in this white paper provides a list of 296 unique potential vegetation types described for Blue Mountains section, their status (whether they qualify as a plant association, plant community type, or plant community), and how they were assigned to plant association groups (PAGs) and potential vegetation groups (PVGs) in a Blue Mountains hierarchical potential vegetation classification system (Powell et al. 2007).

Range of variation (historical range of variability). A characterization of fluctuations in ecosystem conditions or processes over time; an analytical technique used to define the bounds of ecosystem behavior that remain relatively consistent through time (Morgan and others 1994). Values of composition, structure, or another attribute, and falling between upper and lower bounds determined for the attribute (Jennings et al. 2003), are said to be within the range of variation. Attributes whose values occur above the upper bound are said to be 'over-represented;' attributes whose values are below the lower bound are said to be 'under-represented' (see fig. 1). "The range of variation under historic disturbance regimes is an important context to evaluate current and desired conditions; however, it should not necessarily be used as the desired condition itself" (FSH 1909.12, Land Management Planning Handbook, section 43.13 – Range of variation).

Reference conditions. A reference ecosystem or reference conditions can serve as a model for planning ecosystem restoration activities. In its simplest form, the reference is an actual site, its written description (such as historical accounts of a reference area), or both (Society for Ecological Restoration 2004). Reference conditions also refer to a range of variation in ecological structures and processes, reflecting recent evolutionary history and the dynamic interplay of biotic and abiotic factors. Reference conditions generally reflect ecosystem properties that are free of major influence by Euro-American humans (Kaufmann et al. 1994).

Resilience. Intrinsic properties allowing the fundamental functions of an ecosystem to persist in the presence of disturbance; the 'bounce-back' capability of a system to recover from disturbance. "Ecological resilience is the capacity of an ecosystem to absorb disturbance and undergo change while maintaining its essential functions, structures, identity, and feedbacks. Resilience is often synonymous with adaptive capacity, i.e., the ability of a system to reconfigure itself in the face of disturbance or stresses without significant decreases in critical aspects such as productivity or composition" (Drever et al. 2006). Resilience recognizes that systems have a capacity to absorb disturbance, but this capacity has limits and when they are exceeded, the system may rapidly transition to a different state or developmental trajectory (Gunderson et al. 2010). In a climate-change context, resilience is sometimes viewed as analogous to adaptation.

Resistance. Resistance refers to the ability of an ecosystem to remain relatively unchanged in the face of external forces such as disturbance (pulse-type changes) or climate change. Resistance is sometimes viewed as being analogous to stability (Holling 1973), but in a climate-change context, it is often viewed as analogous to mitigation.

Seral stage: A stage of secondary successional development (secondary succession refers to an ecological process of progressive changes in a plant community after stand-initiating disturbance). Four seral stages are recognized: early seral, mid seral, late seral, and potential natural community (Hall et al. 1995).

> **Early seral**: clear dominance of pioneer species (western larch, ponderosa pine, lodgepole pine, etc.); PNC species absent, or present in very low numbers.
>
> **Mid seral**: PNC species are increasing in the forest composition as a result of their active colonization of the site; PNC species are approaching equal proportions with the early-seral species.
>
> **Late seral**: PNC species are dominant, although long-lived, early-seral species (ponderosa pine, western larch, etc.) may still be present in low numbers.

Potential natural community (PNC): the biotic community presumably established and maintained under present environmental conditions; early- or mid-seral species are scarce or absent entirely in the plant composition.

Species composition. Identity of species in an ecosystem (Chapin et al. 2002).

Structural stage. A stage or recognizable condition that relates to the physical orientation and arrangement of vegetation; the size and arrangement (both vertical and horizontal) of trees and tree parts. The following structural stages have been described for forested ecosystems (O'Hara et al. 1996, Oliver and Larson 1996; also see table 3):

Stand initiation: one canopy stratum of seedlings and saplings is present; grasses, forbs, and shrubs typically coexist with the trees.

Stem exclusion: one canopy stratum comprised mostly of pole-sized trees (5-8.9" DBH) is present. The canopy layer may be open (stem exclusion open canopy) on sites where moisture is limiting, or closed (stem exclusion closed canopy) on sites where light is a limiting resource.

Understory reinitiation: two canopy strata are present; a second tree layer is established under an older overstory. Overstory mortality creates growing space for establishment of understory trees.

Old forest: a predominance of large trees (>21" DBH) is present in a stand with one or more canopy strata. On warm dry sites with frequent, low-intensity fires, a single stratum may be present (old forest single stratum). On cool moist sites without recurring underburns, multi-layer stands with large trees in the uppermost stratum may be present (old forest multi strata).

RV REFERENCES AND LITERATURE CITED

This section provides cited literature, along with other references pertaining to the range of variation concept.

With few exceptions, sources contained in this References section are available from the World Wide Web in digital form, and a Digital Object Identifier (doi) is included for these items whenever possible.

[Digital object identifier is an international system used to uniquely identify, and link to, electronic versions of scientific information, primarily journal articles.]

All doi links pertain to formally published sources only; local analysis protocols, monitoring reports, and similar items will not have a doi.

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Appendix 1: Potential vegetation types (PVT) for Blue Mountains section (from Powell et al. 2007)[1]

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
ABGR/ACGL	grand fir/Rocky Mountain maple	PA	CWS912	Warm Very Moist UF	Moist UF
ABGR/ACGL (FLOODPLAIN)	grand fir/Rocky Mountain maple (floodplain)	PA	CWS543	Warm Moderate SM RF	Moderate SM RF
ABGR/ACGL-PHMA	grand fir/Rocky Mountain maple-ninebark	PCT	CWS412	Warm Moist UF	Moist UF
ABGR/ARCO	grand fir/heartleaf arnica	PCT	CWF444	Cold Dry UF	Cold UF
ABGR/ATFI	grand fir/ladyfern	PA	CWF613	Warm High SM RF	High SM RF
ABGR/BRVU	grand fir/Columbia brome	PA	CWG211	Warm Moist UF	Moist UF
ABGR/CAGE	grand fir/elk sedge	PA	CWG111	Warm Dry UF	Dry UF
ABGR/CALA3	grand fir/woolly sedge	PC	CWM311	Warm High SM RF	High SM RF
ABGR/CARU	grand fir/pinegrass	PA	CWG112	Warm Dry UF	Dry UF
ABGR/CLUN	grand fir/queencup beadlily	PA	CWF421	Cool Moist UF	Moist UF
ABGR/COOC2	grand fir/goldthread	PA	CWF511	Cool Dry UF	Cold UF
ABGR/GYDR	grand fir/oakfern	PA	CWF611	Cool Very Moist UF	Moist UF
ABGR/LIBO2	grand fir/twinflower	PA	CWF311	Cool Moist UF	Moist UF
ABGR/POMU-ASCA3	grand fir/sword fern-ginger	PA	CWF612	Cool Very Moist UF	Moist UF
ABGR/SPBE	grand fir/birchleaf spiraea	PA	CWS321	Warm Dry UF	Dry UF
ABGR/SYAL (FLOODPLAIN)	grand fir/common snowberry (floodplain)	PCT	CWS314	Warm Low SM RF	Low SM RF
ABGR/TABR/CLUN	grand fir/Pacific yew/queencup beadlily	PA	CWC811	Cool Wet UF	Moist UF
ABGR/TABR/LIBO2	grand fir/Pacific yew/twinflower	PA	CWC812	Cool Wet UF	Moist UF
ABGR/TRCA3	grand fir/false bugbane	PA	CWF512	Cool Very Moist UF	Moist UF
ABGR/VAME	grand fir/big huckleberry	PA	CWS211	Cool Moist UF	Moist UF
ABGR/VASC	grand fir/grouse huckleberry	PA	CWS811	Cold Dry UF	Cold UF
ABGR/VASC-LIBO2	grand fir/grouse huckleberry-twinflower	PA	CWS812	Cool Moist UF	Moist UF
ABGR-CHNO/VAME	grand fir-Alaska yellow cedar/big huckleberry	PCT	CWS232	Cool Moist UF	Moist UF
ABLA2/ARCO	subalpine fir/heartleaf arnica	PCT	CEF412	Cool Moist UF	Moist UF
ABLA2/ATFI	subalpine fir/ladyfern	PA	CEF332	Cold High SM RF	High SM RF
ABLA2/CAAQ	subalpine fir/aquatic sedge	PCT	CEM123	Cold High SM RF	High SM RF
ABLA2/CACA	subalpine fir/bluejoint reedgrass	PA	CEM124	Cold Moderate SM RF	Moderate SM RF
ABLA2/CADI	subalpine fir/softleaved sedge	PCT	CEM122	Cold High SM RF	High SM RF
ABLA2/CAGE	subalpine fir/elk sedge	PA	CAG111	Cold Dry UF	Cold UF
ABLA2/CARU	subalpine fir/pinegrass	PCT	CEG312	Cool Dry UF	Cold UF
ABLA2/CLUN	subalpine fir/queencup beadlily	PA	CES131	Cool Moist UF	Moist UF
ABLA2/LIBO2	subalpine fir/twinflower	PA	CES414	Cool Moist UF	Moist UF
ABLA2/MEFE	subalpine fir/fool's huckleberry	PA	CES221	Cold Moist UF	Cold UF
ABLA2/POPU	subalpine fir/skunkleaved polemonium	PCT	CEF411	Cold Dry UF	Cold UF
ABLA2/RHAL	subalpine fir/white rhododendron	PCT	CES214	Cold Moist UF	Cold UF
ABLA2/SETR	subalpine fir/arrowleaf groundsel	PA	CEF333	Cold High SM RF	High SM RF
ABLA2/STAM	subalpine fir/twisted stalk	PCT	CEF311	Cool Wet UF	Moist UF
ABLA2/STOC	subalpine fir/western needlegrass	PCT	CAG4	Cold Dry UF	Cold UF

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
ABLA2/TRCA3	subalpine fir/false bugbane	PA	CEF331	Cool Moist UF	Moist UF
ABLA2/VAME	subalpine fir/big huckleberry	PA	CES311	Cool Moist UF	Moist UF
ABLA2/VASC	subalpine fir/grouse huckleberry	PA	CES411	Cold Dry UF	Cold UF
ABLA2/VASC/POPU	subalpine fir/grouse huckleberry/skunkleaved polemonium	PA	CES415	Cold Dry UF	Cold UF
ABLA2/VAUL/CASC5	subalpine fir/bog blueberry/Holm's sedge	PCT	CEM313	Cold High SM RF	High SM RF
ABLA2-PIAL/JUDR	subalpine fir-whitebark pine/Drummond’s rush	PCT	CAG3	Cold Dry UF	Cold UF
ABLA2-PIAL/POPH	subalpine fir-whitebark pine/fleeceflower	PCT	CAF2	Cold Dry UF	Cold UF
ABLA2-PIAL/POPU	subalpine fir-whitebark pine/skunkleaved polemonium	PCT	CAF0	Cold Dry UF	Cold UF
ADPE	maidenhair fern	PCT	FW4213	Warm High SM RH	High SM RH
AGDI	thin bentgrass	PCT	MD4111	Warm Low SM RH	Low SM RH
AGSP	bluebunch wheatgrass	PA	GB41	Hot Dry UH	Dry UH
AGSP-ERHE	bluebunch wheatgrass-Wyeth’s buckwheat	PA	GB4111	Hot Dry UH	Dry UH
AGSP-POSA3	bluebunch wheatgrass-Sandberg’s bluegrass	PA	GB4121	Hot Dry UH	Dry UH
AGSP-POSA3-ASCU4	bluebunch wheatgrass-Sandberg’s bluegrass-Cusick’s milkvetch	PA	GB4114	Hot Dry UH	Dry UH
AGSP-POSA3 (BASALT)	bluebunch wheatgrass-Sandberg’s bluegrass (basalt)	PA	GB4113	Hot Dry UH	Dry UH
AGSP-POSA3-DAUN	bluebunch wheatgrass-Sandberg’s bluegrass-onespike oatgrass	PA	GB4911	Hot Dry UH	Dry UH
AGSP-POSA3-ERPU	bluebunch wheatgrass-Sandberg’s bluegrass-shaggy fleabane	PA	GB4115	Hot Dry UH	Dry UH
AGSP-POSA3 (GRANITE)	bluebunch wheatgrass-Sandberg’s bluegrass (granite)	PA	GB4116	Hot Dry UH	Dry UH
AGSP-POSA3-OPPO	bluebunch wheatgrass-Sandberg’s bluegrass-pricklypear	PA	GB4118	Hot Dry UH	Dry UH
AGSP-POSA3-PHCO2	bluebunch wheatgrass-Sandberg’s bluegrass-Snake River phlox	PA	GB4117	Hot Dry UH	Dry UH
AGSP-POSA3-SCAN	bluebunch wheatgrass-Sandberg’s bluegrass-narrowleaf skullcap	PA	GB4112	Hot Dry UH	Dry UH
AGSP-SPCR-ARLO3	bluebunch wheatgrass-sand dropseed-red threeawn	PCT	GB1911	Hot Dry UH	Dry UH
ALIN/ATFI	mountain alder/ladyfern	PA	SW2116	Warm High SM RS	High SM RS
ALIN/CAAM	mountain alder/bigleaved sedge	PA	SW2114	Warm High SM RS	High SM RS
ALIN/CAAQ	mountain alder/aquatic sedge	PC	SW2126	Warm High SM RS	High SM RS
ALIN/CACA	mountain alder/bluejoint reedgrass	PA	SW2121	Warm Moderate SM RS	Moderate SM RS
ALIN/CADE	mountain alder/Dewey’s sedge	PCT	SW2118	Warm Moderate SM RS	Moderate SM RS
ALIN/CALA3	mountain alder/woolly sedge	PA	SW2123	Warm Moderate SM RS	Moderate SM RS
ALIN/CALEL2	mountain alder/densely tufted sedge	PC	SW2127	Warm Moderate SM RS	Moderate SM RS
ALIN/CALU	mountain alder/woodrush sedge	PC	SW2128	Warm Low SM RS	Low SM RS
ALIN/CAUT	mountain alder/bladder sedge	PA	SW2115	Warm High SM RS	High SM RS
ALIN/EQAR	mountain alder/common horsetail	PA	SW2117	Warm Moderate SM RS	Moderate SM RS
ALIN/GLEL	mountain alder/tall mannagrass	PA	SW2215	Warm High SM RS	High SM RS
ALIN/GYDR	mountain alder/oakfern	PCT	SW2125	Warm Moderate SM RS	Moderate SM RS
ALIN/HELA	mountain alder/common cowparsnip	PCT	SW2124	Warm Moderate SM RS	Moderate SM RS
ALIN/POPR	mountain alder/Kentucky bluegrass	PCT	SW2120	Warm Low SM RS	Low SM RS
ALIN/SCMI	mountain alder/smallfruit bulrush	PCT	SW2122	Warm High SM RS	High SM RS
ALIN-COST/MESIC FORB	mountain alder-redosier dogwood/mesic forb	PA	SW2216	Warm Moderate SM RS	Moderate SM RS
ALIN-RIBES/MESIC FORB	mountain alder-currants/mesic forb	PA	SW2217	Warm Moderate SM RS	Moderate SM RS
ALIN-SYAL	mountain alder-common snowberry	PA	SW2211	Warm Low SM RS	Low SM RS

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
ALPR	meadow foxtail	PCT	MD2111	Warm Low SM RH	Low SM RH
ALRU (ALLUVIAL BAR)	red alder (alluvial bar)	PCT	HAF226	Warm Moderate SM RF	Moderate SM RF
ALRU/ATFI	red alder/ladyfern	PCT	HAF227	Warm High SM RF	High SM RF
ALRU/COST	red alder/redosier dogwood	PC	HAS511	Warm Moderate SM RF	Moderate SM RF
ALRU/PEFRP	red alder/sweet coltsfoot	PCT	HAF211	Warm Moderate SM RF	Moderate SM RF
ALRU/PHCA3	red alder/Pacific ninebark	PA	HAS211	Warm Moderate SM RF	Moderate SM RF
ALRU/SYAL	red alder/common snowberry	PCT	HAS312	Warm Moderate SM RF	Moderate SM RF
ALSI	Sitka alder snow slides	PCT	SM20	Cold Very Moist US	Cold US
ALSI/ATFI	Sitka alder/ladyfern	PA	SW2111	Warm High SM RS	High SM RS
ALSI/CILA2	Sitka alder/drooping woodreed	PA	SW2112	Warm High SM RS	High SM RS
ALSI/MESIC FORB	Sitka alder/mesic forb	PCT	SW2113	Warm Moderate SM RS	Moderate SM RS
ALVA	swamp onion	PCT	FW7111	Cold High SM RH	High SM RH
AMAL	western serviceberry	PCT	SW3114	Hot Low SM RS	Low SM RS
ARAR/FEID-AGSP	low sagebrush/Idaho fescue-bluebunch wheatgrass	PA	SD1911	Warm Moist US	Moist US
ARAR/POSA3	low sagebrush/Sandberg’s bluegrass	PA	SD9221	Hot Dry US	Dry US
ARCA/DECE	silver sagebrush/tufted hairgrass	PA	SW6111	Hot Moderate SM RS	Moderate SM RS
ARCA/POCU	silver sagebrush/Cusick’s bluegrass	PCT	SW6114	Hot Low SM RS	Low SM RS
ARCA/POPR	silver sagebrush/Kentucky bluegrass	PCT	SW6112	Hot Low SM RS	Low SM RS
ARRI/POSA3	stiff sagebrush/Sandberg’s bluegrass	PCT	SD9111	Hot Dry US	Dry US
ARTRV/BRCA	mountain big sagebrush/mountain brome	PCT	SS4914	Warm Moist US	Moist US
ARTRV/CAGE	mountain big sagebrush/elk sedge	PA	SS4911	Cold Moist US	Cold US
ARTRV/FEID-AGSP	mountain big sagebrush/Idaho fescue-bluebunch wheatgrass	PA	SD2911	Warm Moist US	Moist US
ARTRV/POCU	mountain big sagebrush/Cusick’s bluegrass	PA	SW6113	Hot Low SM RS	Low SM RS
ARTRV/STOC	mountain big sagebrush/western needlegrass	PCT	SS4915	Cool Dry US	Cold US
ARTRV-PUTR/FEID	mountain big sagebrush-bitterbrush/Idaho fescue	PCT	SD2916	Hot Moist US	Moist US
ARTRV-SYOR/BRCA	mountain big sagebrush-mountain snowberry/mountain brome	PCT	SD2917	Warm Moist US	Moist US
BEOC/MESIC FORB	water birch/mesic forb	PCT	SW3112	Warm Moderate SM RS	Moderate SM RS
BEOC/WET SEDGE	water birch/wet sedge	PCT	SW3113	Warm High SM RS	High SM RS
CAAM	bigleaved sedge	PA	MM2921	Warm High SM RH	High SM RH
CAAQ	aquatic sedge	PA	MM2914	Warm High SM RH	High SM RH
CACA	bluejoint reedgrass	PA	GM4111	Warm Moderate SM RH	Moderate SM RH
CACA4	silvery sedge	PCT	MS3113	Warm Moderate SM RH	Moderate SM RH
CACU (SEEP)	Cusick’s camas (seep)	PCT	FW3911	Warm Very Moist UH	Moist UH
CACU2	Cusick’s sedge	PA	MM2918	Warm High SM RH	High SM RH
CAGE (ALPINE)	elk sedge (alpine)	PCT	GS3911	Cold Dry UH	Cold UH
CAGE (UPLAND)	elk sedge (upland)	PCT	GS39	Cool Dry UH	Cold UH
CAHO	Hood’s sedge	PCT	GS3912	Cool Moist UH	Cold UH
CALA	smoothstemmed sedge	PC	MW2913	Cold High SM RH	High SM RH
CALA3	woolly sedge	PA	MM2911	Warm Moderate SM RH	Moderate SM RH
CALA4	slender sedge	PC	MM2920	Warm High SM RH	High SM RH

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
CALEL2	densely tufted sedge	PA	MM2919	Warm Moderate SM RH	Moderate SM RH
CALU	woodrush sedge	PA	MM2916	Cold High SM RH	High SM RH
CAMU2	star sedge	PCT	MS3112	Warm Moderate SM RH	Moderate SM RH
CANE	Nebraska sedge	PCT	MM2912	Hot Moderate SM RH	Moderate SM RH
CANU4	torrent sedge	PCT	MM2922	Hot High SM RH	High SM RH
CAPR5	clustered field sedge	PCT	MW2912	Cold High SM RH	High SM RH
CASC5	Holm's sedge	PA	MS3111	Cold High SM RH	High SM RH
CASH	Sheldon's sedge	PCT	MM2932	Hot Moderate SM RH	Moderate SM RH
CASI2	shortbeaked sedge	PCT	MM2915	Warm High SM RH	High SM RH
CAST	sawbeak sedge	PCT	MW1926	Warm High SM RH	High SM RH
CAUT	bladder sedge	PA	MM2917	Warm High SM RH	High SM RH
CAVEV	inflated sedge	PA	MW1923	Warm High SM RH	High SM RH
CELE/CAGE	mountain mahogany/elk sedge	PCT	SD40	Hot Moist US	Moist US
CELE/FEID-AGSP	mountain mahogany/Idaho fescue-bluebunch wheatgrass	PA	SD4111	Hot Moist US	Moist US
CERE2/AGSP	netleaf hackberry/bluebunch wheatgrass	PA	SD5611	Hot Moist US	Moist US
CEVE	snowbrush ceanothus	PCT	SM33	Warm Moist US	Moist US
CILA2	drooping woodreed	PC	MW2927	Cold High SM RH	High SM RH
COST	redosier dogwood	PA	SW5112	Hot Moderate SM RS	Moderate SM RS
COST/SAAR4	redosier dogwood/brook saxifrage	PCT	SW5118	Warm High SM RS	High SM RS
CRDO	Douglas hawthorne	PCT	SW3111	Hot Low SM RS	Low SM RS
DECE	tufted hairgrass	PA	MM1912	Warm Moderate SM RH	Moderate SM RH
ELBE	delicate spikerush	PC	MS4111	Cold High SM RH	High SM RH
ELCI	basin wildrye	PA	GB7111	Hot Very Moist UH	Moist UH
ELPA	creeping spikerush	PA	MW4912	Hot High SM RH	High SM RH
ELPA2	fewflowered spikerush	PCT	MW4911	Cold High SM RH	High SM RH
EQAR	common horsetail	PA	FW4212	Warm Moderate SM RH	Moderate SM RH
ERDO-POSA3	Douglas buckwheat/Sandberg's bluegrass	PCT	FM9111	Hot Dry UH	Dry UH
ERIOG/PHOR	buckwheat/Oregon bladderpod	PA	SD9322	Hot Dry UH	Dry UH
ERST2-POSA3	strict buckwheat/Sandberg's bluegrass	PCT	FM9112	Hot Dry UH	Dry UH
ERUM (RIDGE)	sulphurflower (ridge)	PCT	FM9113	Hot Dry UH	Dry UH
FEID (ALPINE)	Idaho fescue (alpine)	PCT	GS12	Cold Moist UH	Cold UH
FEID-AGSP	Idaho fescue-bluebunch wheatgrass	PA	GB59	Warm Moist UH	Moist UH
FEID-AGSP (RIDGE)	Idaho fescue-bluebunch wheatgrass (ridge)	PCT	GB5915	Warm Moist UH	Moist UH
FEID-AGSP-BASA	Idaho fescue-bluebunch wheatgrass-balsamroot	PA	GB5917	Warm Moist UH	Moist UH
FEID-AGSP-LUSE	Idaho fescue-bluebunch wheatgrass-silky lupine	PA	GB5916	Warm Moist UH	Moist UH
FEID-AGSP-PHCO2	Idaho fescue-bluebunch wheatgrass-Snake River phlox	PA	GB5918	Warm Moist UH	Moist UH
FEID-CAGE	Idaho fescue-elk sedge	PCT	GB5922	Warm Moist UH	Moist UH
FEID-CAHO	Idaho fescue-Hood's sedge	PA	GB5921	Warm Moist UH	Moist UH
FEID-DAIN-CAREX	Idaho fescue-timber oatgrass-sedge	PA	GB5920	Warm Very Moist UH	Moist UH
FEID-KOCR (HIGH)	Idaho fescue-prairie junegrass (high)	PA	GB5913	Cool Moist UH	Cold UH

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
FEID-KOCR (LOW)	Idaho fescue-prairie junegrass (low)	PA	GB5914	Warm Moist UH	Moist UH
FEID-KOCR (MOUND)	Idaho fescue-prairie junegrass (mound)	PA	GB5912	Cool Moist UH	Cold UH
FEID-KOCR (RIDGE)	Idaho fescue-prairie junegrass (ridge)	PA	GB5911	Cool Moist UH	Cold UH
FEVI	green fescue	PCT	GS11	Cold Moist UH	Cold UH
FEVI-CAHO	green fescue-Hood's sedge	PCT	GS1111	Cold Moist UH	Cold UH
FEVI-LULA2	green fescue-spurred lupine	PA	GS1112	Cold Moist UH	Cold UH
GLEL	tall mannagrass	PA	MM2925	Warm High SM RH	High SM RH
GLNE/AGSP	spiny greenbush/bluebunch wheatgrass	PA	SD65	Hot Dry US	Dry US
JUBA	Baltic rush	PCT	MW3912	Hot Moderate SM RH	Moderate SM RH
JUOC/ARAR	western juniper/low sagebrush	PCT	CJS1	Hot Dry UW	Dry UW
JUOC/ARRI	western juniper/stiff sagebrush	PCT	CJS8	Hot Dry UW	Dry UW
JUOC/ARTRV	western juniper/mountain big sagebrush	PCT	CJS2	Hot Moist UW	Moist UW
JUOC/ARTRV/FEID-AGSP	western juniper/mountain big sagebrush/fescue-wheatgrass	PA	CJS211	Hot Moist UW	Moist UW
JUOC/CELE/CAGE	western juniper/mountain mahogany/elk sedge	PCT	CJS42	Hot Moist UW	Moist UW
JUOC/CELE/FEID-AGSP	western juniper/mountain mahogany/fescue-wheatgrass	PCT	CJS41	Hot Moist UW	Moist UW
JUOC/FEID-AGSP	western juniper/Idaho fescue-bluebunch wheatgrass	PA	CJG111	Hot Moist UW	Moist UW
JUOC/PUTR/FEID-AGSP	western juniper/bitterbrush/Idaho fescue-bluebunch wheatgrass	PA	CJS321	Hot Moist UW	Moist UW
LECOW	Wallowa Lewisia	PCT	FX4111	Hot Dry UH	Dry UH
METR	buckbean	PC	FW6111	Warm High SM RH	High SM RH
PERA3-SYOR	squaw apple-mountain snowberry	PCT	SD30	Hot Moist US	Moist US
PHLE2 (TALUS)	syringa bordered strips (talus)	PCT	NTS111	Hot Very Moist US	Moist US
PHMA-SYAL	ninebark-common snowberry	PA	SM1111	Warm Moist US	Moist US
PICO(ABGR)/ALSI	lodgepole pine(grand fir)/Sitka alder	PCT	CLS58	Cool Very Moist UF	Moist UF
PICO(ABGR)/ARNE	lodgepole pine(grand fir)/pinemat manzanita	PCT	CLS57	Cool Dry UF	Cold UF
PICO(ABGR)/CARU	lodgepole pine(grand fir)/pinegrass	PCT	CLG21	Cool Dry UF	Cold UF
PICO(ABGR)/LIBO2	lodgepole pine(grand fir)/twinflower	PCT	CLF211	Cool Moist UF	Moist UF
PICO(ABGR)/VAME	lodgepole pine(grand fir)/big huckleberry	PCT	CLS513	Cool Moist UF	Moist UF
PICO(ABGR)/VAME/CARU	lodgepole pine(grand fir)/big huckleberry/pinegrass	PCT	CLS512	Cool Moist UF	Moist UF
PICO(ABGR)/VAME/PTAQ	lodgepole pine(grand fir)/big huckleberry/bracken	PCT	CLS519	Cool Moist UF	Moist UF
PICO(ABGR)/VASC/CARU	lodgepole pine(grand fir)/grouse huckleberry/pinegrass	PCT	CLS417	Cold Dry UF	Cold UF
PICO(ABLA2)/CAGE	lodgepole pine(subalpine fir)/elk sedge	PCT	CLG322	Cold Dry UF	Cold UF
PICO(ABLA2)/STOC	lodgepole pine(subalpine fir)/western needlegrass	PCT	CLG11	Cold Dry UF	Cold UF
PICO(ABLA2)/VAME	lodgepole pine(subalpine fir)/big huckleberry	PCT	CLS514	Cool Moist UF	Moist UF
PICO(ABLA2)/VAME/CARU	lodgepole pine(subalpine fir)/big huckleberry/pinegrass	PCT	CLS516	Cool Moist UF	Moist UF
PICO(ABLA2)/VASC	lodgepole pine(subalpine fir)/grouse huckleberry	PCT	CLS418	Cold Dry UF	Cold UF
PICO(ABLA2)/VASC/POPU	lodgepole pine(subalpine fir)/grouse huckleberry/polemonium	PCT	CLS415	Cold Dry UF	Cold UF
PICO/ALIN/MESIC FORB	lodgepole pine/mountain alder/mesic forb	PC	CLM511	Cold Moderate SM RF	Moderate SM RF
PICO/CAAQ	lodgepole pine/aquatic sedge	PA	CLM114	Cold High SM RF	High SM RF
PICO/CACA	lodgepole pine/bluejoint reedgrass	PC	CLM117	Cold Moderate SM RF	Moderate SM RF
PICO/CALA3	lodgepole pine/woolly sedge	PC	CLM116	Cold Moderate SM RF	Moderate RF

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
PICO/CARU	lodgepole pine/pinegrass	PA	CLS416	Cool Dry UF	Cold UF
PICO/DECE	lodgepole pine/tufted hairgrass	PA	CLM115	Cold Moderate SM RF	Moderate SM RF
PICO/POPR	lodgepole pine/Kentucky bluegrass	PCT	CLM112	Cold Low SM RF	Low SM RF
PIEN/ATFI	Engelmann spruce/ladyfern	PCT	CEF334	Cold High SM RF	High SM RF
PIEN/BRVU	Engelmann spruce/Columbia brome	PCT	CEM125	Cold Low SM RF	Low SM RF
PIEN/CADI	Engelmann spruce/softleaved sedge	PA	CEM121	Cold High SM RF	High SM RF
PIEN/CILA2	Engelmann spruce/drooping woodreed	PC	CEM126	Cold Moderate SM RF	Moderate SM RF
PIEN/COST	Engelmann spruce/redosier dogwood	PA	CES511	Cold Moderate SM RF	Moderate SM RF
PIEN/EQAR	Engelmann spruce/common horsetail	PA	CEM211	Cold Moderate SM RF	Moderate SM RF
PIEN/SETR	Engelmann spruce/arrowleaf groundsel	PCT	CEF335	Cold High SM RF	High SM RF
PIMO/DECE	western white pine/tufted hairgrass	PCT	CQM111	Warm Moderate SM RF	Moderate SM RF
PIPO/AGSP	ponderosa pine/bluebunch wheatgrass	PA	CPG111	Hot Dry UF	Dry UF
PIPO/ARAR	ponderosa pine/low sagebrush	PCT	CPS61	Hot Moist UF	Dry UF
PIPO/ARTRV/CAGE	ponderosa pine/mountain big sagebrush/elk sedge	PCT	CPS132	Hot Dry UF	Dry UF
PIPO/ARTRV/FEID-AGSP	ponderosa pine/mountain big sagebrush/fescue-wheatgrass	PA	CPS131	Hot Dry UF	Dry UF
PIPO/CAGE	ponderosa pine/elk sedge	PA	CPG222	Warm Dry UF	Dry UF
PIPO/CARU	ponderosa pine/pinegrass	PA	CPG221	Warm Dry UF	Dry UF
PIPO/CELE/CAGE	ponderosa pine/mountain mahogany/elk sedge	PA	CPS232	Warm Dry UF	Dry UF
PIPO/CELE/FEID-AGSP	ponderosa pine/mountain mahogany/fescue-wheatgrass	PA	CPS234	Hot Dry UF	Dry UF
PIPO/CELE/PONE	ponderosa pine/mountain mahogany/Wheeler’s bluegrass	PA	CPS233	Hot Dry UF	Dry UF
PIPO/ELGL	ponderosa pine/blue wildrye	PA	CPM111	Warm Dry UF	Dry UF
PIPO/FEID	ponderosa pine/Idaho fescue	PA	CPG112	Hot Dry UF	Dry UF
PIPO/PERA3	ponderosa pine/squaw apple	PCT	CPS8	Hot Dry UF	Dry UF
PIPO/POPR	ponderosa pine/Kentucky bluegrass	PCT	CPM112	Hot Low SM RF	Low SM RF
PIPO/PUTR/AGSP	ponderosa pine/bitterbrush/bluebunch wheatgrass	PCT	CPS231	Hot Dry UF	Dry UF
PIPO/PUTR/CAGE	ponderosa pine/bitterbrush/elk sedge	PA	CPS222	Warm Dry UF	Dry UF
PIPO/PUTR/CARO	ponderosa pine/bitterbrush/Ross sedge	PA	CPS221	Warm Dry UF	Dry UF
PIPO/PUTR/FEID-AGSP	ponderosa pine/bitterbrush/Idaho fescue-bluebunch wheatgrass	PA	CPS226	Hot Dry UF	Dry UF
PIPO/RHGL	ponderosa pine/sumac	PCT	CPS9	Hot Dry UF	Dry UF
PIPO/SPBE	ponderosa pine/birchleaf spiraea	PCT	CPS523	Warm Dry UF	Dry UF
PIPO/SYAL	ponderosa pine/common snowberry	PA	CPS522	Warm Dry UF	Dry UF
PIPO/SYAL (FLOODPLAIN)	ponderosa pine/common snowberry (floodplain)	PA	CPS511	Hot Low SM RF	Low SM RF
PIPO/SYOR	ponderosa pine/mountain snowberry	PA	CPS525	Warm Dry UF	Dry UF
POFR/DECE	shrubby cinquefoil/tufted hairgrass	PA	SW5113	Warm Moderate SM RS	Moderate SM RS
POFR/POPR	shrubby cinquefoil/Kentucky bluegrass	PCT	SW5114	Warm Low SM RS	Low SM RS
POPR (DEGEN BENCH)	Kentucky bluegrass (degenerated bench)	PCT	MD3112	Cool Moist UH	Cold UH
POPR (MEADOW)	Kentucky bluegrass (meadow)	PCT	MD3111	Warm Low SM RH	Low SM RH
POSA3-DAUN	Sandberg’s bluegrass-onespike oatgrass	PA	GB9111	Hot Dry UH	Dry UH
POTR/ALIN-COST	quaking aspen/mountain alder-redosier dogwood	PCT	HQS222	Warm Moderate SM RF	Moderate SM RF
POTR/ALIN-SYAL	quaking aspen/mountain alder-common snowberry	PCT	HQS223	Warm Moderate SM RF	Moderate SM RF

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
POTR/CAAQ	quaking aspen/aquatic sedge	PCT	HQM212	Warm High SM RF	High SM RF
POTR/CACA	quaking aspen/bluejoint reedgrass	PCT	HQM123	Warm Moderate SM RF	Moderate SM RF
POTR/CALA3	quaking aspen/woolly sedge	PA	HQM211	Warm Moderate SM RF	Moderate SM RF
POTR/MESIC FORB	quaking aspen/mesic forb	PCT	HQM511	Warm Moderate SM RF	Moderate SM RF
POTR/POPR	quaking aspen/Kentucky bluegrass	PCT	HQM122	Hot Low SM RF	Low SM RF
POTR/SYAL	quaking aspen/common snowberry	PCT	HQS221	Hot Moderate SM RF	Moderate SM RF
POTR2/ACGL	black cottonwood/Rocky Mountain maple	PCT	HCS114	Warm Moderate SM RF	Moderate SM RF
POTR2/ALIN-COST	black cottonwood/mountain alder-redosier dogwood	PA	HCS113	Warm Moderate SM RF	Moderate SM RF
POTR2/SALA2	black cottonwood/Pacific willow	PA	HCS112	Hot Moderate SM RF	Moderate SM RF
POTR2/SYAL	black cottonwood/common snowberry	PCT	HCS311	Hot Moderate SM RF	Moderate SM RF
PSME/ACGL-PHMA	Douglas-fir/Rocky Mountain maple-mallow ninebark	PA	CDS722	Warm Moist UF	Moist UF
PSME/ACGL-PHMA (FLOODPLAIN)	Douglas-fir/Rocky Mountain maple-mallow ninebark (floodplain)	PA	CDS724	Warm Moderate SM RF	Moderate SM RF
PSME/CAGE	Douglas-fir/elk sedge	PA	CDG111	Warm Dry UF	Dry UF
PSME/CARU	Douglas-fir/pinegrass	PA	CDG121	Warm Dry UF	Dry UF
PSME/CELE/CAGE	Douglas-fir/mountain mahogany/elk sedge	PCT	CDSD	Warm Dry UF	Dry UF
PSME/HODI	Douglas-fir/oceanspray	PA	CDS611	Warm Moist UF	Moist UF
PSME/PHMA	Douglas-fir/ninebark	PA	CDS711	Warm Dry UF	Dry UF
PSME/SPBE	Douglas-fir/birchleaf spiraea	PA	CDS634	Warm Dry UF	Dry UF
PSME/SYAL	Douglas-fir/common snowberry	PA	CDS622	Warm Dry UF	Dry UF
PSME/SYAL (FLOODPLAIN)	Douglas-fir/common snowberry (floodplain)	PA	CDS628	Warm Low SM RF	Low SM RF
PSME/SYOR	Douglas-fir/mountain snowberry	PA	CDS625	Warm Dry UF	Dry UF
PSME/TRCA3	Douglas-fir/false bugbane	PCT	CDF313	Warm Moderate SM RF	Moderate SM RF
PSME/VAME	Douglas-fir/big huckleberry	PA	CDS812	Warm Dry UF	Dry UF
PUPA	weak alkaligrass	PA	MM2926	Warm High SM RH	High SM RH
PUTR/AGSP	bitterbrush/bluebunch wheatgrass	PA	SD3112	Hot Moist US	Moist US
PUTR/FEID-AGSP	bitterbrush/Idaho fescue-bluebunch wheatgrass	PA	SD3111	Warm Moist US	Moist US
RHAL2/MESIC FORB	alderleaved buckthorn/mesic forb	PCT	SW5117	Warm Moderate SM RS	Moderate SM RS
RHGL/AGSP	smooth sumac/bluebunch wheatgrass	PA	SD6121	Hot Dry US	Dry US
RIBES/CILA2	currants/drooping woodreed	PCT	SW5111	Warm High SM RS	High SM RS
RIBES/GLEL	currants/tall mannagrass	PCT	SW5116	Warm High SM RS	High SM RS
RIBES/MESIC FORB	currants/mesic forb	PCT	SW5115	Warm Moderate SM RS	Moderate SM RS
SAAR4	brook saxifrage	PCT	FW6113	Warm High SM RH	High SM RH
SACO2/CAPR5	undergreen willow/clustered field sedge	PC	SW1128	Cold High SM RS	High SM RS
SACO2/CASC5	undergreen willow/Holm’s sedge	PA	SW1121	Cold High SM RS	High SM RS
SACO2/CAUT	undergreen willow/bladder sedge	PCT	SW1127	Cold High SM RS	High SM RS
SAEA-SATW/CAAQ	Eastwood willow-Tweedy willow/aquatic sedge	PC	SW1129	Warm High SM RS	High SM RS
SAEX	coyote willow	PA	SW1117	Hot Moderate SM RS	Moderate SM RS
SALIX/CAAQ	willow/aquatic sedge	PA	SW1114	Warm High SM RS	High SM RS
SALIX/CACA	willow/bluejoint reedgrass	PC	SW1124	Warm Moderate SM RS	Moderate SM RS
SALIX/CALA3	willow/woolly sedge	PA	SW1112	Warm Moderate SM RS	Moderate SM RS

PVT CODE	PVT COMMON NAME	STATUS	ECOCLASS	PAG	PVG
SALIX/CAUT	willow/bladder sedge	PA	SW1123	Warm High SM RS	High SM RS
SALIX/MESIC FORB	willow/mesic forb	PCT	SW1125	Warm Moderate SM RS	Moderate SM RS
SALIX/POPR	willow/Kentucky bluegrass	PCT	SW1111	Warm Low SM RS	Low SM RS
SARI	rigid willow	PCT	SW1126	Hot Moderate SM RS	Moderate SM RS
SASC/ELGL	Scouler willow/blue wildrye	PC	SW1130	Cool Moist US	Cold US
SCMI	smallfruit bulrush	PA	MM2924	Warm High SM RH	High SM RH
SETR	arrowleaf groundsel	PA	FW4211	Warm High SM RH	High SM RH
SPCR (RIVER TERRACE)	sand dropseed (river terrace)	PA	GB1211	Hot Dry UH	Dry UH
STOC	western needlegrass	PCT	GS10	Cool Moist UH	Cold UH
SYAL/FEID-AGSP-LUSE	common snowberry/fescue-wheatgrass-silky lupine	PCT	GB5121	Warm Moist US	Moist US
SYAL/FEID-KOCR	common snowberry/Idaho fescue-prairie junegrass	PCT	GB5919	Warm Moist US	Moist US
SYAL-ROSA	common snowberry-rose	PCT	SM3111	Warm Moist US	Moist US
SYOR	mountain snowberry	PCT	SM32	Warm Moist US	Moist US
TSME/VAME	mountain hemlock/big huckleberry	PA	CMS231	Cold Dry UF	Cold UF
TSME/VASC	mountain hemlock/grouse huckleberry	PA	CMS131	Cold Dry UF	Cold UF
TYLA	common cattail	PCT	MT8121	Hot High SM RH	High SM RH
VEAM	American speedwell	PA	FW6112	Warm High SM RH	High SM RH
VERAT	false hellebore	PC	FW5121	Warm Moderate SM RH	Moderate SM RH

[1] This appendix is organized alphabetically by PVT code. Column descriptions are:

PVT CODE provides an alphanumeric code for each of 296 potential vegetation types described for Blue Mountains section.

PVT COMMON NAME provides a common name for each potential vegetation type.

STATUS provides classification status for each potential vegetation type: PA is Plant Association; PCT is Plant Community Type; PC is Plant Community.

ECOCLASS codes are used to record potential vegetation type determinations.

PAG (Plant Association Group) and PVG (Potential Vegetation Group) are two levels of a mid-scale potential vegetation hierarchy; PAG and PVG codes use the following abbreviations: SM is Soil Moisture, UF is Upland Forest physiognomic class, UW is Upland Woodland physiognomic class, US is Upland Shrubland physiognomic class, UH is Upland Herbland physiognomic class, RF is Riparian Forest physiognomic class, RS is Riparian Shrubland physiognomic class, and RH is Riparian Herbland physiognomic class.

APPENDIX 2: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continuously evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper,

specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

These papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of Blue Mountains dry forests: Silvicultural considerations
5	Site productivity estimates for upland forest plant associations of Blue and Ochoco Mountains
6	Blue Mountains fire regimes
7	Active management of Blue Mountains moist forests: Silvicultural considerations
8	Keys for identifying forest series and plant associations of Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created opening, minimum stocking, and reforestation standards from Umatilla National Forest Land and Resource Management Plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: A process paper
16	Douglas-fir tussock moth: A briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of Blue and Wallowa Mountains
21	Historical fires in headwaters portion of Tucannon River watershed

Paper #	Title
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree
25	Important Blue Mountains insects and diseases
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: Some ecosystem management considerations
28	Common plants of south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of Umatilla National Forest
30	Potential vegetation mapping chronology
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of "Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins" – Forest vegetation
33	Silviculture facts
34	Silvicultural activities: Description and terminology
35	Site potential tree height estimates for Pomeroy and Walla Walla Ranger Districts
36	Stand density protocol for mid-scale assessments
37	Stand density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: Forestry direction
39	Updates of maximum stand density index and site index for Blue Mountains variant of Forest Vegetation Simulator
40	Competing vegetation analysis for southern portion of Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for Umatilla National Forest
42	Life history traits for common Blue Mountains conifer trees
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: Vegetation management considerations
46	Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in northern Blue Mountains: Regeneration ecology and silvicultural considerations
48	Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for Umatilla National Forest: A range of variation analysis
51	Restoration opportunities for upland forest environments of Umatilla National Forest

Paper #	Title
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: An environmental education activity
55	Silviculture certification: Tips, tools, and trip-ups
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman National Forests
57	State of vegetation databases on Malheur, Umatilla, and Wallowa-Whitman National Forests
58	Seral status for tree species of Blue and Ochoco Mountains

REVISION HISTORY

May 2010: Rudiments of this white paper were prepared, in December 1998, as a 5-page enclosure with an Eastside Screens policy and direction letter (issued by Forest Supervisor Jeff Blackwood) dealing specifically with HRV ranges. This rudimentary product was the first version formatted with a new white-paper template (see top of page 1) and posted to the Forest's white-paper website.

March 2012: minor formatting and text edits were made; table 8 was revised to incorporate revised RV ranges from Schmitt and Powell (2012).

November 2012: minor formatting and text edits were made, including additional literature references; a table of contents was added; an appendix was added describing the white paper system, including a list of available white papers.

January 2014: formatting and text edits were made throughout, including a minor revision of the white paper template format on page 1; additional verbiage about Fire Regime Condition Class (FRCC) assessments was added; and in response to requests from Forest Service users of this white paper, substantial additional verbiage about the relationships and interactions between project planning and RV analysis was added as a new section entitled "Project planning and RV."

July 2014: minor edits were made throughout. The primary change was to update RV ranges for forest structural stages (table 5) so they are identical to those included in a draft Environmental Impact Statement for Forest Plan revisions for the three Blue Mountains national forests.

March 2019: additional literature and a new figure relating to FRCC was added, and some text edits and reformatting changes were made.